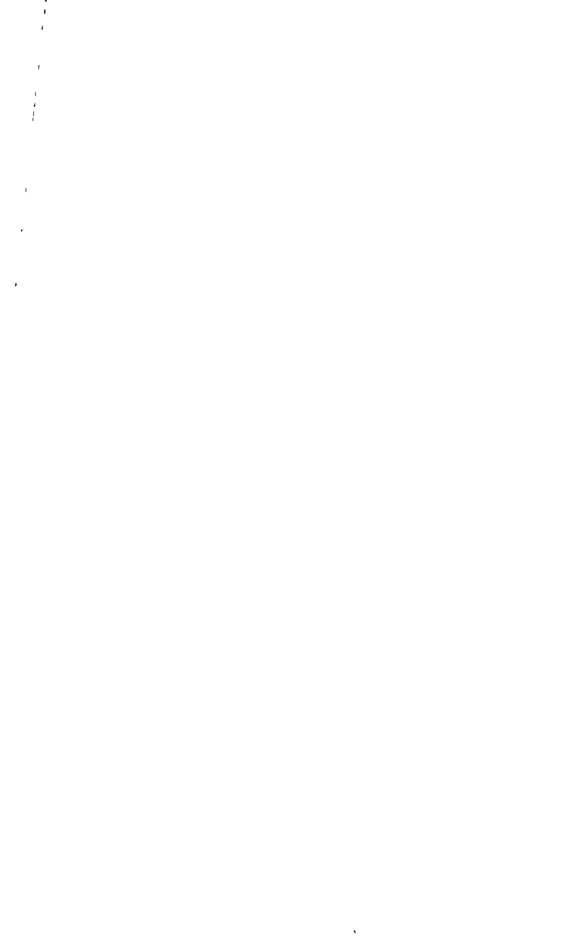
FRACTURES AND RELATED INJURIES



A TEXTBOOK OF
FRACTURES AND RELATED INJURIES

BY

J. GRANT BONNIN

M.B., B.S. ([illegible]), F.R.C.S. ([illegible])

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LONDON

WILLIAM HEINEMANN · MEDICAL BOOKS · LTD

1957

First Published, 1957

Printed in Great Britain

PREFACE

THE continued expansion of knowledge both of fractures and of its borderline subjects, which are not the less important, as without a sound knowledge of both the standards of treatment of trauma cannot be maintained, have encouraged the production of a book which is more than a students' manual, but without pretence to be encyclopaedic. The fundamentals of fracture treatment remain the same, and are those to be found also in a smaller edition "A Complete Outline of Fractures." It was found impossible to maintain the size of this volume and yet do justice to the interest of the subject. Additions and modifications are the sign of a living book. Continued additions eventually make a book unsuitable for the simpler needs of students and compromise is impossible.

In the production of this volume I have had the assistance of many members of the staff of the Central Middlesex Hospital. Mr. T. G. I. James, M.Ch., B.Sc., F.R.C.S., has relieved me from the responsibilities of the chapter on fractures of the skull, where his special knowledge of the intracranial complications of fracture has been made available in a succinct form. Though strictly outside the domain of fractures, it is knowledge essential for the practitioner and specialist in traumatic surgery alike, forming with plastic surgery, the surgery of abdominal injury, and arterial surgery, the corner-stones of traumatic surgery. Dr. J. D. A. Gray, T.D., F.R.C.P.E., D.P.H., has prepared the pages on that continually expanding subject, the antibiotics. Dr. G. Discombe, M.D., B.Sc., has supplied brief notes on blood transfusion, and Mr. J. D. Fergusson, M.D., F.R.C.S., notes on abdominal and genito-urinary injury. To all of them I would like to express my thanks for the enrichment of the book.

The subject of fractures of the face and jaw, demanding as it does very special experience and opportunities, has been written by Mr. J. N. Barron, F.R.C.S. I am deeply indebted to him for this kindness, and for the relief of exploring theoretically the subject in which his practical experience is so large. To the many radiologists who have suffered much in producing what I thought to be the best radiograph illustrating a particular point I am deeply grateful and slightly apologetic. The last, but by no means least of these, is Dr. F. Pygott, M.B., D.P.H., D.M.R.E. It is to his patience and his staff that many of the new illustrations are due.

My publishers have accepted this new volume with the kindness with which they accepted my first, and I remain deeply indebted to them for their encouragement and assistance.

51 Harley St.,
London, W.1.

ACKNOWLEDGEMENTS

THE author and the publisher are grateful to the following firms who have kindly allowed the use of illustrations and supplied blocks for the figures mentioned :—

Messrs. Allen & Hanbury : 134, 140, 147, 148.

Messrs. Down Bros. 55, 56, 124, 129, 130, 131, 132, 138, 142, 149.

The London Splint Co. : 57, 58, 59, 125, 126, 127, 128, 133, 146, 201, 226, 254, 502, 504, 510, 511, 512, 513.

Messrs. Paul B. Hoeber : 17 and 20 ; taken from their publication "Special Cytology," Vol. II, edited by Edmund V. Cowdry.

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D. Rose. 50.

Messrs. John Wright & Sons, *British Journal of Surgery:* 421, 422, 423

Harvey & Blythe Ltd. : 90, 91, 92, 93, 94, 95, 96, 97, 98, 99.

CONTENTS

PART ONE

Fractures in General

that while the swelling will be greater, there will be little or no hæmorrhage. Pain and limitation of movement, together with an effusion will be common (Fig. 1). This condition is not infrequently confused with a partial rupture of a ligament, which is casually referred to as "severe sprain."

Partial rupture of a ligament is accompanied by hæmorrhage, *and severe pain and swelling. Joint stability is, however, little affected* This may accompany a subluxation. Complete rupture of a ligament is inevitably accompanied by more severe signs of hæmorrhage often a hæmarthrosis, and detectable instability of the joint It is an inevitable accompaniment of a dislocation.



A. A strain There is no rupture of the ligamentous fibres or of its periligamentous tissues.



B. A sprain. There has been intraligamentous rupture of fibres, but the sheath is intact.



C *Partial rupture of a* ligament, often called a "severe sprain".



D. *Complete rupture of a* ligament.

Fig. 1. The varieties of injury to a ligament.

An *epiphyseal separation* is a fracture in which the line of separation lies wholly or partly in the epiphyseal line. The majority of epiphyseal separations are more correctly defined as fracture separations, a small triangle of the metaphysis accompanying the separated epiphysis.

The predisposing causes of fractures. The liability to fracture is chiefly determined by the individual's activities which in turn are closely related to age. From ten to forty years, fractures are more common because the individual is then in the most active years of his life. Certain fractures show an exception to this ruling, notably fracture of the neck of the femur. The male is liable to more fractures because of his work, and greater activity at sport, but such fractures as Colles's fracture are more common in the female for reasons outlined in Chapter XXII. Accidents may be grouped as domestic (*greater female liability*), *industrial* (*greater male liability*), street and transport accidents (approximately equal sex liability).

More important, from the point of view of treatment, are the morbid bone conditions which render the patient more susceptible to fracture. These may be grouped as follows:

1. **General bone diseases.** Osteomalacia, rickets, senile atrophy, fragilitas ossium, osteogenesis imperfecta, hyperparathyroidism, Paget's disease.

2. **Nervous diseases.** These result in local bone atrophy from disuse, or increased liability to fall. Poliomyelitis, tabes and the paraplegias and diplegias are examples of such conditions.

3. **Local bone disease.**

INFLAMMATORY.	Acute.	Osteomyelitis.
	Chronic.	Tuberculous, syphilitic gummata, Brodie's abscess.
NEOPLASTIC.	Primary.	Osteoclastoma, sarcoma.
	Secondary.	Carcinoma, particularly from the breast, prostate and thyroid.

The effects of these lesions on union will be more fully discussed in Chapter XI, but senile atrophy of bones scarcely comes into the pathological category, and must be discussed here. It occurs much later in men than in women, in whom it often commences after the menopause, and is accompanied by an increase in subcutaneous fat, strongly suggestive of an endocrine disturbance. Such bones are susceptible to fracture from slighter injuries than normal bones, and the influence of the condition can well be seen in the following table of the age and sex incidence of Colles's fracture.

AGE AND INCIDENCE OF COLLES'S FRACTURE

Age	Male	Female	
10-15	19	6	
15-20	20 Highest male incidence.	10	
20-25	11	10	Males . 99
25-30	6	15	Females . 264
30-35	6	10	
35-40	7	7	Total . 365
40-45	5	19	
45-50	2	16	
50-55	8	40 Highest female incidence	
55-60	4	38	
60-65	4	33	
65-70	3	27	
70-on.	4	28	

Exciting causes of fractures. Rarely a fracture may occur with a pathological basis in which the weight of the limb or movement in bed is sufficient to cause fracture. Such lesions are called spontaneous. Many varieties of fracture, *e.g.*, of the spine, have been found following convulsion therapy, now happily avoided by the use of curare. We are concerned here with the fractures due to trauma, and these may be grouped as arising from :



FIG. 2. A transverse fracture, characteristically produced by direct violence (See Fig. 278)

1. Direct violence.
2. Indirect violence.
3. Muscular strain.
4. Bone fatigue.

Direct violence. The bone is broken directly below the point of impact of the blow, and the fracture, due to bending (Fig 6), may be transverse or, if the blow is severe, comminuted. Comminuted fractures are the common result of direct injury by missiles, such as shrapnel or bullets. Damage to the overlying soft tissues is frequent, and so the fracture is often " open " or " compound." The force of the blow is usually spent in producing the fracture, and is not as a rule concerned with the displacement of the bones. Characteristic examples



FIG. 3 An oblique fracture, the result of bending strain.



FIG 4. A helical fracture following torsional strain, usually called spiral (See Fig 277.)



FIG 5 A common type of fracture, due to bending, half transverse and half oblique produced by the mechanism explained in Figs 6, 7 and 8.

of direct violence are fractures of both bones of the leg where they are broken at the same level which is the level of the blow. Injuries from direct violence consequently may occur at any point struck, while with indirect violence the bone tends to break at its weakest point.

Bony processes, such as the medial humeral epicondyle, are particularly susceptible to direct violence, while the foot frequently suffers from weights being dropped upon it

Indirect violence. The force transmitted to the bone is one of bending (Fig. 6), leverage, rotation or compression, and the bone yields at sites known to be structurally weak. Such a fracture is the usual fracture of the clavicle, where in transmitting an abnormal force from the arm to the trunk the bone snaps at its weakest point In this case the force is a combination of leverage and compression More interesting are the spiral or helical fractures which occur in the long bones particularly the humerus and tibia, where rotational force can be developed by the forearm or the foot

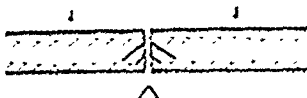


Fig 6 A transverse fracture due to bending strain on close examination always shows small oblique cracks running from the fracture line towards the surface of compression



Fig 7 Occasionally the main line of fracture follows one of these finer lines producing the half oblique half transverse fracture of Fig 5



Fig 8 Less commonly the fracture runs along the fissures on either side of the point of compression, and separates a chip of bone This chip always has its base on the side of compression, and so when present can be used to determine the direction of the bending strain (See Figs 280, 604)

Helical (or Spiral) Fractures can always be recognised by certain peculiar characteristics In the radiographs two components can always be seen, first a long almost vertical component, which, if there has been no displacement, may remain in close approximation, and second, a highly sinuous component, shorter, and more transverse, uniting the ends of the vertical fissure The first represents the hinge on which the second S-shaped portion opens out if the rotation has continued As a consequence the wavy portion always shows a greater width of fracture line (Figs 4, 277.) If the surface of the bone on which each component lies can be identified, and this requires at least two radiographs, the direction of rotation

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FIG 5 A common type of fracture, due to bending, half transverse and half oblique, produced by the mechanism explained in Figs 6, 7 and 8.

3. According to the line of fracture :

Oblique
Spiral (helical).
Transverse
Comminuted.

SIMPLE FRACTURE is the term applied to any complete or incomplete uncomplicated fracture.

COMPLETE FRACTURE. The line of fracture runs across the bone dividing it into two or more entirely separate portions (Figs. 2-5.)

INCOMPLETE FRACTURE The line of fracture does not run entirely through the bone so that part is intact and serves as a support for the fractured ends (Fig. 10).

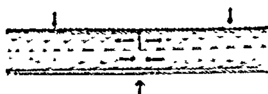


Fig. 9. The method of production of a greenstick fracture. Compare with the previous figures, showing the results of a bending strain acting on a full bone. In a greenstick fracture the bone breaks on the side of the outline undergoing traction. The bone on the side of the compression remains intact

GREENSTICK FRACTURE. This is a classical variety of incomplete fracture in the young. Owing to the mechanical forces developed inside a bent hollow rod, a compression strain is developed on the inside of the bend, and a tension strain in the outer half of the bone Bone, which shows the same physical qualities as cast iron, is most resistant to *compression* and least resistant to *tension*. Fracture of the outer half of the bone therefore occurs leaving the inner half of the bone intact. As the continuity of the bone is not lost, function may remain good, and the fracture may not be noticed till a lump of callus appears on the bone. This is frequently seen in greenstick fractures of the clavicle in children

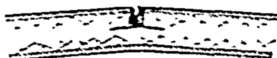


Fig. 10. A greenstick fracture.

In a few cases the bone may be bent without any fracture being visible in the radiograph This only occurs in " green " bones or in cancellous bone The condition is treated similarly to fracture but immobilisation need not be so prolonged. In greenstick fracture the deformity is often marked, and during reduction the bone is not infrequently broken This is not always due to a further fracture of the bone, but due to impaction of the bone on the inner side simulating incomplete fracture.

INFRACTION FRACTURES (" Bamboo fractures "). This is another variety of incomplete fracture occurring in young bones. As a result

can be determined. Thus in Fig. 4 the vertical component lies behind, and the direction of rotation of the lower fragment is to the right, or of the upper fragment to the left.

Fractures from indirect violence are rarely compound, and then as a rule indirectly so There is usually a gross displacement of the bones, and damge to soft parts, from continuation of the force or the falling of the body.

Muscular violence. Fractures from muscular contraction characteristically affect two sites, the olecranon and the patella. They are due to the peculiar position of these bones together with the strength of the muscles inserted into them, which may exert a sudden immense force in the effort to throw a ball or to regain balance. Very rarely a long bone snaps from placing excessive voluntary strain on it, *e.g.*, the humerus in a woman wringing out clothes ; or a rib in a severe bout of coughing.

Bone fatigue. " March fracture " of the metatarsals has long been recognised as due to repeated minor trauma which may summate and produce a fracture, or result in proliferative periosititis to strengthen the weak area without a fracture becoming visible. The condition has now been recognised as affecting other sites, notably the neck of the femur, and the upper third of the tibia (Fig. 585). It is characteristically seen in the adolescent subjected to undue exertion over a long period, and affects sites liable to peculiar strain in maintianing the body weight The condition appears to be related to the similar phenomenon of fatigue in metals, the inorganic substance of the bone slowly altering in a crystalline configuration until a complete cleavage plane appears (see p. 545).

Varieties of Fracture

Fractures may be classified in a number of ways, all interlocking with each other. They may be divided up according to the mechanisms previously described, or :

1. According to whether the fracture communicates with the outside air .

Simple, or "closed."

Compound or " open " { Direct. / Indirect.

2. According to the degree of fracture :

Complete. { Impacted. / Unimpacted.

Incomplete. { Greenstick. / Infraction.

contact is lost, and retention becomes difficult. If a fragment is totally dislocated from its blood supply it may undergo avascular necrosis, but this as a rule interferes in no way with union unless the fragment is very large. Large fragments usually survive as some periosteal attachment remains and then play the part of a living bone graft, the fracture merely requiring a little longer to consolidate. The mechanism producing the single triangular fragment is explained in Figs. 6, 7 and 8.

EPIPHYSEAL SEPARATIONS. These occur on the metaphyseal side of the epiphyseal line. They are usually fracture separations, a small portion of metaphysis being broken off with the epiphysis. This fragment is important in reduction, as by catching on the metaphysis it may prevent over-correction. There is no bony crepitus palpable in a pure epiphyseal separation as the abrasion of the surfaces is softened by the cartilage (Fig. 14).



Fig. 14. Separation of the lower epiphysis of the radius showing the small wedge of metaphysis which is fractured and remains attached to it, in this case displaced dorsally.

Crepitus may however be obtained from the small piece of metaphysis which is fractured, and so the sign is unreliable. Provided the epiphysis is cleanly fractured on the metaphyseal side, and the epiphyseal plate remains intact no interference with growth need be anticipated if the separation is reasonably well reduced. If the epiphyseal plate is fractured there is a likelihood of interference with growth. This is due to the occurrence of premature synostosis between epiphysis and diaphysis at the site of damage to the epiphyseal plate. Growth continues in the undamaged portion of the epiphyseal plate with resultant distortion (Figs. 590, 591).

LIGAMENT TRACTION FRACTURES (Sprain fractures). Ligaments as a rule yield at their bony insertion rather than tear. When this occurs a small flake of bone is removed with the ligament, and this can be seen in the X-ray. This lesion is frequently seen in the region of the ankle. Its importance depends on the degree of luxation of the joint such a separation has allowed, and this must be estimated clinically and radiologically. The treatment of the lesser isolated lesion is that of a ruptured ligament (Figs. 650, 662).

COMPOUND FRACTURES (Open fractures). When the fracture communicates with the outside air it is said to be compound, or

of compression violence there is a small expansion of the bone at the junction of the cancellous end of the bone and the compact bone of the shaft. This results in a slight irregularity resembling the ridge on a bamboo stem being seen in the X-ray. This appearance may



FIG. 11. An infraction fracture of the lower end of the radius Compare with Fig 370.

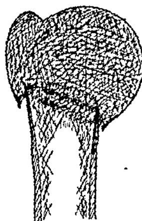


FIG. 12. An impaction fracture of the upper end of the humerus. Compare with Fig. 263.

be seen in both the lateral and antero-posterior views of the bone, but is frequently seen in one view only, the other view showing a more marked deformity. The lesion is most commonly seen in the lower end of the radius in children, occurring a little above the site of Colles' fracture in the adult (Figs. 11, 370).



FIG. 13. A comminuted fracture. The comminutions are multiple, due to direct violence Fig. 8 illustrates the type of comminution due to indirect (bending) violence.

IMPACTED FRACTURES. Following the break in the bone the continuation of the force jams the broken ends into one another, and the resultant interlocking of bony spicules gives the bone a moderate degree of rigidity, which may allow a considerable degree of function It is characteristically seen in fractures of the upper end of the humerus, where the cancellous head is driven over the compact bone of the humeral shaft. Impaction is important in aiding fixation and indicates, as a rule, that little displacement has occurred (see p 469).

COMMINUTED FRACTURES Where the bone is broken into more than two fragments the term comminuted is applied. Where there is marked comminution the steadying effect of pushing the two broken ends into

contact is lost, and retention becomes difficult. If a fragment is totally dislocated from its blood supply it may undergo avascular necrosis, but this as a rule interferes in no way with union unless the fragment is very large. Large fragments usually survive as some periosteal attachment remains and then play the part of a living bone graft, the fracture merely requiring a little longer to consolidate. The mechanism producing the single tri-angular fragment is explained in Figs. 6, 7 and 8.

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COMPOUND FRACTURES (Open fractures) When the fracture communicates with the outside air it is said to be compound, or

open. The importance lies in the enormously increased risks of infection of the bone. The fracture may be compound from rupture of the skin covering the bone, or of a mucous surface such as the mouth, bladder or nose. Where the force producing the injury has resulted in breaking the skin over the bone the fracture is *directly* compound, but where the displacement after the injury has resulted in a sharp spicule of bone being driven through the skin it is said to be *indirectly* compound. The importance of this observation is that the conveyance of infection from outside inwards is much more likely in the direct lesion than in the indirect, though the withdrawal of the spicule through the skin may draw dirt in with it. Indirect compound fractures of this type are almost exclusively met with in the leg, associated with spiral fracture of the tibia. As the spicule of bone may have withdrawn before the case is seen the importance of a careful examination of the skin for puncture wounds needs emphasis. It is also to be borne in mind that all wounds over fractures do not necessarily communicate with them, and in the repair of such wounds every effort should be made to preserve an undamaged wall of tissue between the fracture and the wound.

FURTHER READING

The following general text-books are available for consultation :

SPEED, KELLOG. "Fractures." C. V. Mosby. London, Henry Kimpton, 4th Ed., 1942. (Contains further reference lists.)

SCUDDER, C. L. "The Treatment of Fractures." W. B. Saunders & Co., Philadelphia and London, 11th Ed., 1938.

MATTI, H. "Die Knochenbruche und ihre Behandlung." Julius Springer, Berlin, 1931 (Contains [illegible]

KEY and CONWELL. "The [illegible] and Sprains." C. V. Mosby.

WATSON JONES. "Fractures [illegible] Edinburgh, E. & S. Livingstone, 4th Ed., 1, 1952.

BOHLER, L. "The Treatment of Fractures" Translated from the 13th German Edition, Vol 1 Grune and Stratton New York and London, 1956

CHARNLEY, J "The Closed Treatment of Common Fractures." E. & S. Livingstone, 1st Ed., 1954.

CHAPTER II

THE REPAIR OF FRACTURES

SOME knowledge of the process of repair in bone is essential to the satisfactory treatment of fractures. The primary stimulus to the formation of bone is still a quarrelling ground for the erudite, and no attempt can be made here to give more than an account of the observed facts and their relation to treatment. It is to be noted

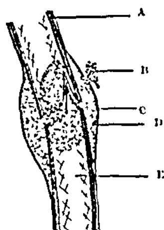


FIG. 15. Hæmatoma around the fracture

A, Compact bone of the shaft
B, Hæmorrhage escaping into muscles through torn periosteum.
C, Periosteum.
D, Hæmatoma under stripped up periosteum
E, Medullary cavity.

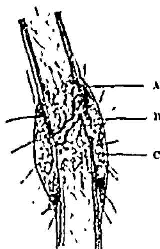


FIG. 16. Stage of granulation tissue.

A, Active dilated blood vessels.
B, Remaining unorganised hæmatoma.
C, Organised granulation tissue.

though the processes in a healing fracture have been separated for discussion, they may all be taking place in different parts of the same healing tissues at the same time (Fig. 24).

1. **Hæmatoma.** Immediately following a fracture there is an outpouring of blood into the tissue spaces around the bone ends, from the marrow tissues, the torn periosteum, and the damaged muscles. The amount of blood will vary depending on the amount of periosteal tearing, the comminution and displacement of the bone ends, the laceration of the surrounding tissues, and the size of the blood-vessels torn and the resistance offered by the tissues. If displacement

occurs, a cavity containing lacerated muscle, fragments of bone, bone marrow, and fascia will be found around and between the ends of the bones. Occasionally even tendons and nerves will be included. In fractures involving joints fragments of articular cartilage and ligaments are added. The blood remains fluid in the centre of this mass

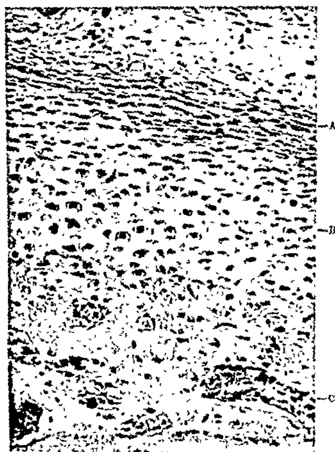


FIG 17 Section of the proliferated periosteal tissue of a four-day-old fracture.
A, Cellular proliferation of the periosteum
B, Cartilaginous differentiation of the cells. No blood vessels present
C, Early formation of bone around vascular spaces.
The section shows a full range of differentiated cells between fibroblasts and bone

for some hours, clotting usually about the end of the first day Fresh handling of the limb produces fresh hæmorrhage and an increase in size of the hæmatoma mass. The common conception of the periosteum forming a limiting membrane to such a mass of jumbled tissues is quite erroneous. Only in children is the periosteum of any thickness and strength In the adult it is a friable membrane, which usually remains attached to the bone, and tears along the margins of

the fissures. The wall of the fracture hæmatoma is thus formed almost entirely of soft tissues.

Organisation of the hæmatoma. Aseptic inflammatory changes commence at once in the tissues around the fracture and organisation of the clot commences at the junction of the clot and living tissues. From the second to the thirteenth day the hæmorrhagic mass becomes encapsulated with a fibrous tissue layer produced by the activity of fibroblasts appearing from the capillary networks invading the hæmatoma. This progresses layer on layer

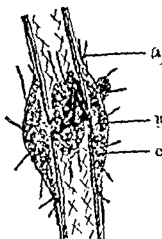


Fig. 18. Commencing organisation of granulation tissue, and formation of callus.

A, Callus commencing to form in the angle between the bone and the periosteum.
B, Granulation tissue organised in the medullary cavity.
C, Subperiosteal granulation tissue

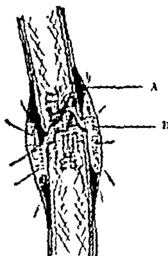


Fig. 19. The organisation of the callus to bone.

A, Bone appearing in the angle between the periosteum and the shaft, where it is first visible, as a fluffy shadow in the X-ray.
B, Organised callus

till the whole mass is vascularised and replaced by granulation tissue. The outer layers of fibrous tissue commence to differentiate into fibrocartilage and hyaline cartilage first. The fragments of dead bone are absorbed in various ways and soft tissues interposed are also absorbed as a rule, without the progress of union being affected. This fibrous tissue framework often extends into the muscles around the fracture which have been bruised, and so they may be involved in the further process of repair. With the organisation of the callus this tends to retrogress, but a persistent fibrosis may remain with consequent adhesion of the muscle to the periosteum, and loss of contractility. This is seen frequently in the quadriceps.

Organisation of the granulation tissue. For reasons variously

attributed to the presence of excessive calcium in the region, to the mechanical stresses of the region, and to inherent properties in the cells of the periosteum, the granulation tissue commences to differentiate itself in the direction of bone. Two processes become obvious. First, certain fibroblasts lay down collagen fibrils in their exoplasm, and assume the characteristics of osteoblasts. Further osteoblasts develop around these centres, and the older cells then deposit lime salts among the collagen fibrils forming callus. This change first becomes visible in the angle between the elevated periosteum and the shaft of the bone, where there is a good blood supply from the first, and this process spreads itself through the granulation tissue

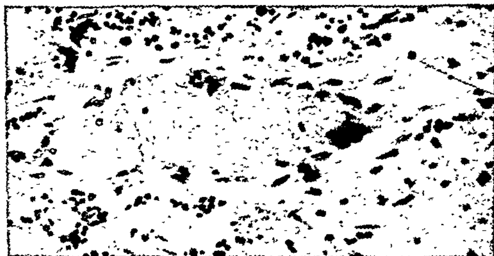


FIG. 20 Osteoclasts arranged around a bony trabeculæ.

down to the fracture site At this stage we have the first appearance of changes visible in the X-ray, usually somewhere about the tenth day As early callus is not very radio-opaque, the time of its appearance on a film will be much affected by the quality of the radiograph and the density of overlying tissues

The second process commences opposite the bone ends and here certain fibroblasts grow to resemble cartilage cells. The number of these cells which appears seems to depend on the amount of movement at the fracture site and is minimal with absolute fixation of the bones. As it is some abnormality in the production of these cells which leads to false joint formation this is an important point.

Organisation of callus. Callus has appeared in the angle between the periosteum and the shaft on the sixth day, and becomes obvious to the X-ray on the tenth day, but it requires twenty-five days before it is firm. Two processes are occurring in this callus. New bone is being differentiated from the young osteoblasts and the cartilage cells, and at the same time the ends of the fractured bones, which are

at first coated with a layer of dead cells, are being remodelled. This appears to occur from resorption of the lime in the exoplasm of the osteoblasts which become larger and their cell walls less definite. Several of these cells lying in contact with one another will thus appear to be in a bony lacuna, and, owing to the poor definition of their cell walls will appear as multi-nucleated masses, to which the name of "osteoclast" has been given. These groups of cells are merely osteoblasts in an anabolic phase preparatory to undergoing a katabolic phase in conformity with the demands of their new situation. Should a small piece of bone become avascular, this

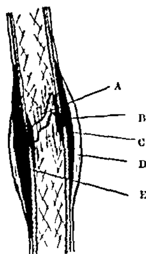


FIG. 21. The fracture firmly united by new bone.

A, Internal callus B, Intermediate callus C, External callus D, Resolving external callus E, See Fig 22



FIG 22 Union in a transverse fracture of the femur, showing the increased strength of callus deposited on the side of the fracture under compression strain

process cannot occur from internal cellular change, and must occur very slowly from outside cellular activity.

Organisation of bone. Callus first becomes converted into bone at the point where it is first laid down. Fine trabecular bone is laid down which slowly extends throughout the organising callus, which, once it has firmly joined the bone ends, commences to shrink

in size. As time progresses this bone organises itself into compact and cancellous bone, the so-called intermediate callus between the bone ends becoming organised into compact bone, continuous with the compact bone of the shaft. This reorganisation of the bone takes place with definite regard to the stress and strain passing through the fracture site. If the bone is meeting at a slight angle a compression strain will occur on the inner aspect of the angle and a tension strain on the outer aspect. Compact bone will be laid down most rapidly, and solidly in the area under compression. This important fact is the clue to the success of weight bearing in producing union in fractures of the lower limb.

Over a long period of time the bone will slowly be restored to normal size, and the prominence of the callus decreased. If the bone is mal-united the further growth of the bone will tend to restore it to the normal. In young people this power of adaptation is very great, but it diminishes rapidly with the cessation of growth. The development of bone at the fracture site occurs in accordance with the demands of function, and so is greatly aided by the activity of the muscles and joints in relation to the fracture. For some time after a fracture the bone at the fracture site remains increased in density and thickness and slightly tender.

The Formation of Bone

Without going into the experimental evidence we can say that the following factors influence the formation of bone. It is uncertain which is the primary stimulus, but it is possible that there is an interaction of several factors.

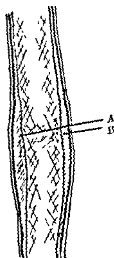


FIG. 23. The organised new bone.

A, B, Slight thickening of the shaft indicates the site of the old fracture, the bone on the inside of the curve being slightly thicker than that on the outside.

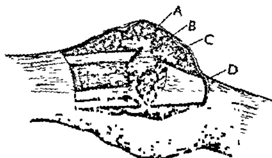


FIG. 24 Section of a healing fracture —
A, Outer fibrous sheath, continuous with periosteum.
B, Calcification spreading among organised fibrous tissue.
C, Organising hæmatoma.
D, Subperiosteal calcification and new bone formation.

1. The quantity and activity of the fibroblasts. The cause of their differentiation into osteoblasts is unknown.

2. The presence of some inorganic calcium and phosphorus possibly the factor stimulating the fibroblasts.

3. The presence of a good blood supply to the part.

4. The quality of the blood. It must contain adequate calcium, phosphorus and vitamins.

It is to be noted, however, that the blood calcium, phosphorus and phosphatase are not significantly altered during healing.

5. The amount of movement at the fracture site. This modifies the differentiation of fibroblasts in an unknown manner resulting in increased production of cartilage, and combined with other factors in false joint formation.



FIG. 25. Well united fracture in the young, showing an avascular sclerotic fragment incorporated in the callus.

Certain of these factors are under our control. We can assure that the patient has an adequate diet, and that the movement at the fracture site is restricted. The presence of fibroblasts and adequate calcium and phosphorus at the fracture site is a normal occurrence in a healthy individual Only the blood supply is liable to variation. Normally this is assured by the active granulation tissue, but if an inflammatory process occurs in the vicinity of the fracture the blood supply may be excessively increased. This will result in a decalcification of the region and delay in the union, which will take longer to consolidate

If the fracture site becomes infected still further vascular disturbance occurs, with increased destruction of tissues, and healing is further delayed.

The sequence of tissue changes described is constant for all fractures, but varies in rate in different parts of the fracture. The exact time of the various changes varies with :—

1. Individual bones.
2. Age of the patient
3. Type of fracture (oblique or transverse).
4. Site of fracture (shaft or end of bone).
5. Amount of displacement of the fractured ends.

6. Volume of interposed fragments and injured tissue.

7. General constitutional conditions, avitaminosis, undernourishment, chronic nephritis, and other illnesses.

The strength of union in the early days will depend on the area of callus surrounding the bone ends, imparting rigidity to the fracture. Reduction in the size of the hæmatoma by operative treatment of the fracture will therefore delay the development of rigidity, though this may be offset by the closer interlocking of the fracture.

Radiological changes. The importance of these changes as a guide to the union of fractures has perhaps been over-estimated. As a guide to the type and degree of non-union radiographs are of inestimable value, but in the early stages, and often until the bone is fit clinically for weight-bearing, the density of the shadow cast by the fine lamellar bone in the callus is slight and is obscured by the shadow of the soft tissues. Clinically firm union may be present before there is radiological confirmation, and if this is not acted on the patient may be prevented from weight bearing for an unnecessary length of time Having elicited the facts of clinical union, the radiograph may be used as a guide to the strength of the union. Having decided that the union is not sound, the radiograph may be helpful to decide whether this change is temporary or of a more permanent nature (see Chapter III)

At all stages in the healing process all radio-opaque material at the fracture site is bone, and this is commonly seen first at the tenth day at the point where the bone, the attached periosteum, and the elevated periosteum meet The necessity for removing all splinting and plaster when making a radiological attempt to estimate union should not need emphasis, but is often neglected.

Avascular bone necrosis

The improvement of radiological apparatus and technique has brought to light an interesting series of changes which occur in a fragment of bone deprived of its blood supply. Bone may be rendered avascular in various ways. A fragment, as in Fig 25, may be thrown off from the cortex into the hæmatoma surrounding a fracture, and so be deprived of its blood supply. In fractures of the long bones particularly the tibia, a double fracture (Fig 605) may deprive a section of part or whole of its supply This may delay union at one fracture site, or at both, and not infrequently non-union becomes established at one fracture. It does not necessarily follow that the fragment will die. Fine fragments may survive in the tissue fluids and in larger fragments the superficial cells survive. The bone can however no longer take part in its usual metabolism and its density must remain constant for a considerable

time. With the increased blood supply and fibroblastic activity in the vicinity of the fracture, and the enforced rest of the limb, decalcification occurs in the vicinity of the fracture in which the isolated fragment cannot partake. It therefore appears, by virtue of retaining its normal density, much denser than the surrounding

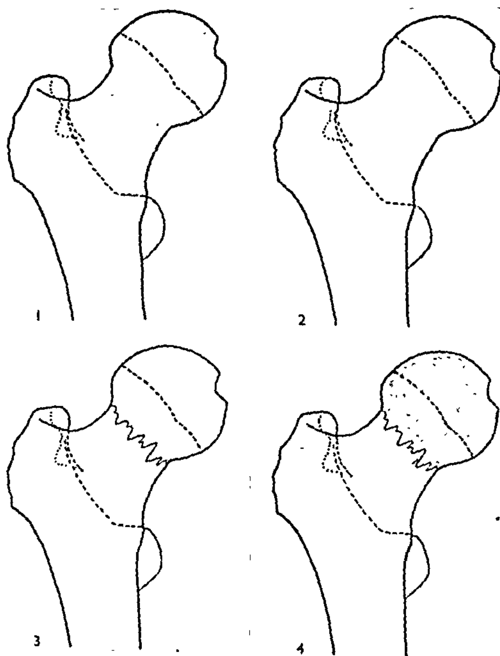


FIG 26 The changes in density of bone associated with avascular necrosis.

1. The normal [illegible]
2. Decr [illegible]
3. Frac [illegible]
   the [illegible]
   The [illegible], retains its normal density.
4. After some time there is a deposit of calcium in the head which becomes denser than normal.

parts Such a fragment will be slowly absorbed and replaced by living bone in the manner of a bone graft.

Certain portions of bone may be deprived of their blood supply if this is dependent on a few vessels susceptible to pressure or division. Thus in fractures of the navicular the main blood supply enters across a transverse line to which the axis of the bone lies obliquely. The proximal half of the bone is articular and the blood supply

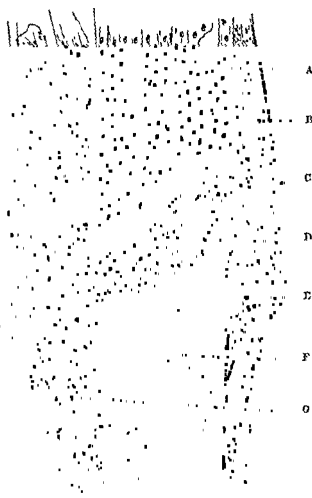


FIG 27 [illegible]
living [illegible]
of a [illegible]
bone.

A, Living bone as shown by the presence of nuclei in the bony lacunæ.
B, Subperiosteal proliferation of osteoblasts forming new bone. (Fig 16)
C, Dead bone on the surface, as indicated by the empty lacunæ, undergoing absorption.
D, New cancellous bone uniting the graft to its bed.
E New bone formed by some surviving cells in the periosteum of the graft.
F, Dead bone of the graft, showing the empty lacunæ.
G, New bone in the medullary cavity.

limited, fractures therefore lying proximal to this line (Fig. 386) may cut the proximal pole off from its blood supply and it undergoes avascular necrosis. Following immobilisation of the wrist the proximal pole first appears to be increased in density. This is apparent from about the third week on, becoming gradually more marked as the decalcification in the vicinity progresses. With the passage of time and if kept at rest the fragment is invaded with capillaries, absorbed, and rebuilt by a creeping replacement. Its density thus slowly returns to that of the surrounding bones. On the commencement of exercise it partakes in the general increase in density of the bones of the limb, but its surface will not be found so clean or well defined as the rest of the bones. The length of time taken for this process varies from six to eighteen months. The replaced bone lacks the finer modelling of the original bone and its cartilage covered surfaces are defective. Though the bone has ostensibly recovered it has taken the first backward step in a series of retrograde changes which lead ultimately to a degenerative arthritis.

Should the avascular fragment not be immobilised, the revascularisation of the bone is prevented by recurrent damage to the capillary loops, and the bony fragment comes to lie like a foreign body in a fibrous tissue sheath. From the fluids bathing it it adsorbs calcium and phosphorus which crystallise in its interstices and greatly increase its density relative to all bones normal or decalcified. A similar reaction is seen in loose bony fragments in joints. The density achieved is unmistakable. It indicates that the fragment is acting as a foreign body and that any attempt at obtaining union is a waste of time. Where the bone forms part of a joint, as in the case of the navicular, it may be tolerated for a time, but eventually leads to a degenerative arthritis. It is therefore best excised.

The blood supply of small bones is variable, and it is not always possible to forecast the occurrence of avascular necrosis from the line of fracture. Crushing and impaction of cancellous surfaces, with subsequent thrombosis, may play a part, while the temporary disturbance of the whole blood supply to a limb may precipitate a case by causing a thrombosis. Movements or unsuitable splintage may damage or pull on ligaments carrying the remaining channels of supply. All these may therefore influence the occurrence of necrosis and make its occurrence unpredictable. Certain bones from the delicacy of their blood supply are particularly susceptible to the condition, and must be watched for such changes by serial radiographs at monthly intervals. These bones are :—

1. Lunate } after fracture or dislocation (p. 416).
2. Navicular } (p. 407).

3. The head of the femur, after fracture or dislocation (p. 484).

4. The talus following dislocations or fracture dislocations (p. 620).

The importance of avascular necrosis is threefold :—

(*a*) It delays and may prevent union entirely.

(*b*) When union has occurred a considerably longer period must elapse before use of a limb is permitted if the new bone is not to be crushed or eroded at once

(*c*) The replaced bone, if partaking in a joint, and this is usually the case, is degenerate and eventually after a longer or shorter period leads to a degenerative arthritis.

Bone grafts

Similar radiological changes may be seen in bone grafts, and vary only in degree from the successful to the unsuccessful graft. In the successful graft the bone cells survive on the surface and rapidly unite with new bone from the soft tissues nearby to bed the graft firmly The rest of the graft which appears denser than the surrounding bone is slowly replaced by creeping replacement and gradually assumes a density similar to the surrounding bones. With compact bone the replacement of the graft is slow, and attention has therefore been directed to the use of cancellous bone in the hope that it will revascularise more rapidly. In certain cases in which the compact graft is not needed to maintain length or stability its use has been very successful

In unsuccessful bone grafts the graft rapidly assumes the characteristics of a foreign body becoming markedly increased in density and lying separated from the new bone formed in the vicinity by a channel of granulation tissue. Should the callus provoked be successful in bridging the gap the graft may be successful in spite of its failure to " take."

FURTHER READING

Development and Structure

MURRAY, P. F. D. " Bone." Cambridge University Press, 1936.
COWDRY. " Special Cytology." Hoeber, New York. Vol. 2. 1932.

Repair

[illegible] " Physiology of Bone." London, 1928.
[illegible] in the presence of Aseptic Necrosis, from and Vascular Destructions," *J. Bone and* [illegible]
WATSON JONES and ROBERTS. " Calcification, Decalcification and O[illegible] tion," *Brit. J. Surg.*, 1934, 21, 4[illegible]

HERTZ, J. "Studies in the Healing of Fractures." Oxford University Press, 1936. (With special reference to the significance of the vitamin content of the diet.)
HAM, A. "Histological Study of the Early Phases of Bone Repair," *J. Bone and Joint Surg.*, 1930, **12**, 827.
UNST, M. A., and JOHNSON, R. W. "The Healing of Fractures in Man under Clinical Conditions," *J. Bone and Joint Surg.*, 1943, **35**, 375.
BICK, E. M. "Structural Patterns of Callus in Fractures of the Long Bones," *J. Bone and Joint Surg.*, 1948, **30A**, 141.
EGGERS, G. W. M., *et al.* "The Influence of the Contact-Compression Factor on Osteogenesis Insurgical Fractures," *J. Bone and Joint Surg.*, 1949, **31A**, 693.

Avascular Necrosis

WATSON JONES and ROBERTS. "Significance of the Density of Bone Shadows," *Brit. J. Surg.*, 1934, **21**, 467.
SANTOS. "Changes in the Head of the Femur after Intracapsular Fracture," *Arch. Surg.*, 1930, **21**, 470.
FAIRBANK, H. A. T. "Increased and Decreased Density of Bone," *Brit. J. Surg.*, 1939, **27**, 1.
COMPERE, E. L. "Avascular Necrosis of Large Segmental Fracture Fragments of the Long Bones," *J. Bone and Joint Surg.*, 1949, **31A**, 47.

Bone Grafts

HENDERSON, M. "Bone Grafts in Ununited Fractures," *J. Bone and Joint Surg.*, 1938, **20**, 635.
See also references in Chapter X.

3. The head of the femur, after fracture or dislocation (p. 484).

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FURTHER READING

Development and Structure

Murray, P. F. D. " Bone." Cambridge University Press, 1936.
Cowdry. " Special Cytology." Hoeber, New York. Vol 2, 1932.

Repair

Leriche and Policard. " Physiology of Bone." London, 1928.
Phemister. " Repair of Bone in the presence of Aseptic Necrosis, from Fractures, Transplantations and Vascular Destructions," *J. Bone and Joint Surg.*, 1930, 12, 769.
Watson Jones and Roberts. " Calcification, Decalcification and Ossification," *Brit. J. Surg.*, 1934, 21, 461.

serious pressure may be produced. The avoidance of swelling is important as it interferes with the diagnosis, reduction, and more particularly retention of a fracture It must be combated at once by elevation and fixation of the part, and later may be dispersed by massage and effleurage. Accompanying swelling and bruising fracture blisters are often seen. They are serous effusions, often blood-stained, between the dermis and epidermis. The more superficial the bone, and the larger the hæmatoma, the more likely these blisters are to occur. They take twelve to twenty-four hours to appear, but do not appear if the skin is supported by an unpadded plaster, though if this plaster is split they will appear along the line of cleavage.

Loss of function is a classical, but variable sign. Impacted or green-stick fractures may show little loss of function. A patient may walk on an abduction fracture of the neck of the femur, and it is an unfortunate commonplace that fractures of the spine are not recognised till the patient has walked for a few days thus compressing the fractured vertebra, and producing deformity.

Deformity. This is another variable feature. It may be gross or only detectable by careful measurement. In compound fractures the wound may be considered as part of the deformity, and in it the fractured bone ends may be seen. Previous deformities from disease or accident must be considered.

Abnormal mobility. In order to detect this one may have to inflict considerable pain, and on this ground alone it is often better neglected. In order to detect it one must have a knowledge of the normal degree of movement of joints, and one must where possible compare it with the intact limb, to allow for individual variations. Mobility may be excessive at a joint, or in one direction at a joint, or it may be detected at a point where there is no joint. This latter sign is certain evidence of fracture. The nearer the lesion is to a joint the more the abnormal mobility will be camouflaged by the normal joint movements, and the more difficult it is to determine.

A less emphasised point is the loss of mobility at certain joints such as the hip and shoulder after fracture in the vicinity. This is noted in impacted fractures where function is not entirely lost, and is due to several factors, the spasm of surrounding muscles from the pain, the irregularity of joint surfaces acting mechanically to prevent movement, and distension of the joint capsule from blood and synovial fluid.

Loss of transmitted movement from one part of a bone to another is certain evidence of fracture. It is commonly elicited in fractures of the humerus, when the head may not rotate under the deltoid on rotating the elbow. Similarly the head of the radius

CHAPTER III

SIGNS AND SYMPTOMS OF FRACTURES

WITH the exception of spontaneous and fatigue fractures, a history of injury is always obtained, though in cases such as fracture of the neck of the femur, produced by a stumble, the injury may be very slight. In cases of fatigue fracture such as "march" fracture of a metatarsal there may be no history of injury, merely one of pain over a period of time.

PAIN is a prominent feature of all fractures unless the patient has some neurological lesion such as tabes, producing anæsthesia, or is hopelessly drunk. A sufficiency of alcohol may be quite efficient as an anæsthetic for fracture reduction.

The elicitation of pain may be important in examination. Compressing the thorax antero-posteriorly may produce pain over the site of a fractured rib, and similarly the pressure backwards on both anterior superior iliac spines may give localised pain in fractures of the pelvis

The localisation of the pain is always important, and in many cases is the main distinguishing feature between one fracture and the next. The general tenderness which is the usual accompaniment of the pain is of little value unless it can be localised. In the more superficial bones this localisation is of great value in diagnosing the site of the fracture, but it must be remembered that a subperiosteal hæmatoma is very tender, and may in certain cases cause legitimate confusion requiring an X-ray to distinguish it. In finding the point of maximum tenderness it is best to get the patient to localise it with one finger first, and then to follow that up with a careful one-finger examination of the part

SWELLING. The degree of swelling varies with a number of factors. The site of fracture, the dependency of the part, the activity of the circulation, the amount of displacement, and the treatment, all influence it. It is particularly marked in elbow fractures where the tissues seem to leave space for a large effusion of blood, and in the femur where there is often gross displacement It is less marked in fractures of the wrist and lower leg. In these

[illegible]

room for expansion if the limb is placed in a complete plaster, and

Radiography

The necessity to X-ray the patient will have been decided by the previous examination, on one of the following grounds.

1. To establish accurate diagnosis of position and type in an undoubted fracture.
2. To establish the diagnosis in a doubtful fracture.
3. To produce evidence of absence of bony damage in medico-legal cases.
4. At the request of the patient or another doctor.

X-rays produce the only detailed and accurate evidence of the lesion and are invaluable for reduction. No patient should be deprived of an X-ray, because the condition can be diagnosed without it, if further treatment is contemplated. Without the assistance of a radiograph the doctor cannot be said to be exercising reasonable care in the handling of the case because he is not putting himself in possession of all the available facts, a prerequisite of "reasonable care." Certain fractures, such as that of the clavicle, require no X-ray, or the private patient may be spared the expense, but the matter should be put to him, and if the accident is anything but domestic an X-ray should be taken for medico-legal purposes.

In the treatment of a fracture the following X-rays will be necessary :

1. Films before reduction.
2. Films after reduction, and after any further attempts if the first is not satisfactory.
3. Films during retention.

    If by continuous traction. As often as is necessary. Change of weight, position, or suspension demand it at least once weekly.

    If by fixation. At the end of a week or earlier if there is likely to be displacement.

    Every time the plaster or retaining apparatus is changed.
4. At the end of treatment.

Certain variations of this will be found possible in minor fractures, but in a fracture such as the femur all the above-mentioned films will be necessary for efficient treatment.

X-rays must fulfil certain conditions to be of full value in the assistance they offer Unless the conditions set out below are adhered to the X-ray may be more confusing than helpful. The films must be accurately aligned antero-posterior and lateral views, and in certain fractures must be supplemented by oblique views. Unless the films are accurately taken in these directions it will be

may not turn under the thumb when the shaft of the radius is fractured.

✓ CREPITUS. This is not such a useful sign as it sounds. The issue may be confused by other forms of crepitus, such as capsular crepitus, tenosynovitis, or that due to arthritis. Where the fracture involves cartilaginous surfaces it will not be felt, and the separation of a epiphysis will produce a soft crepitus from the friction of bone on cartilage. Unless there is some need for the information the elicitation of crepitus is to be avoided on account of the pain it produces.

The Examination of the Patient

This will include not only an evaluation of the points mentioned, but a careful examination of the whole of the body to exclude other lesions carried out in the following order.

1. HISTORY. Of the present accident.
   Of past accidents or deformities.
2. INSPECTION. Comparison with the normal limb.
3. PALPATION. Comparison of bony points, etc.
4. MENSURATION. Comparison of length or girth of the limb, and the use of special lines such as Nelaton's.
5. GENERAL EXAMINATION :
   (*a*) For injuries to other parts of the limb
   (*b*) For injuries elsewhere in the body.
   (*c*) To exclude associated disease.
6. SPECIAL EXAMINATION. X-ray.
   (*a*) Plain.
   (*b*) Radiography under strain. (Ruptures of ligaments.)
   (*c*) Tomography. (Fractures of the spine.)
   (*d*) Contrast. Arthrography. (Intra-articular injury, *e g.*, torn menisci.)

It is quite possible to treat a fracture of the skull in an unconscious patient and overlook a fracture of the spine with no deformity. One has seen a fracture of the shaft of the femur on one side duly recognised while an impacted pertrochanteric fracture of the other side was missed. It is always advisable to examine the other joints and bones concerned in the transmission of the fracturing force to the trunk. Thus a Colles's fracture may be treated in a sling and the fact overlooked that at the same time an impacted fracture of the upper end of the humerus was present, with resultant permanent stiffness of the shoulder. The after-treatment of a Colles's fracture should in any case avoid this, but all patients do not yet get adequate after-treatment.

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difficult to estimate the displacement in many cases. A film in one direction only may completely overlook displacement in another direction, and a second film at right angles to it is an absolute necessity, often for diagnosis, and always for correct orientation. An oblique fracture without displacement may only show on one film as there will be no changes in bony density to record in an X-ray passing through it at right angles to the fracture line. In certain fractures it may be necessary to give the patient a local or general anæsthetic to place the limb in a suitable position for both X-rays, but though this is irksome it is a far more satisfactory way of solving difficulties than by taking stereoscopic X-rays.

The film must be of a suitable density and clarity to show the bony trabeculæ or else a fine fracture will be overlooked. In order to check accurately the position of fractures of long bones the film must be of sufficient size to include the nearest joint, and it is often desirable to have a film including the joints at both ends of the bone. No X-rays should be taken before reduction without first removing strapping or metal splints as they may obscure important points. After reduction it may not always be possible to get the retentive apparatus out of the way, but this should be attempted wherever possible. The translucency of plaster to X-rays is one of its great advantages.

Missed Fractures and Errors of Interpretation

Fractures are most commonly missed because on clinical examination it is thought unnecessary to X-ray the part. Such an error is commonly seen in fractures of the spine where 70 per cent. of cases are not diagnosed at the first examination. In this particular case the taking of an accurate history of the fall is all-important as it will raise suspicion, which will demand a confirmatory X-ray.



FIG 28 Well developed os trigonum, showing the features which distinguish it from a recent fracture

The difficulties which may occur with X-rays have been mentioned above, oblique fractures only showing in one film, or fractures of one bone being overlain by the shadow of another bone, and such like. Fine fractures in the small bones may only be detected by a hand lens This may be noted in the carpal navicular. On the first examination the bone is regarded as normal, but three weeks later on account of pain

a further X-ray is taken. This may show some rarefaction in the bone along a definite fracture line. In such cases a careful examination of the first film will show a fine crack which has been overlooked (Fig. 415). It must never be forgotten that the finding of one fracture does not preclude the presence of a second, and the whole of the film must be carefully searched.

The following may be mistaken for recent fractures :

1. The persistance of a fracture line from an old fracture of the skull.

2. The foramina of nutrient vessels, often prominent in the metacarpals.

3. Sesamoid bones. See Fig. 674.

4. Accessory bones. See Figs. 28, 206.

5. Old collapse fractures of the vertebræ.

6. Old ununited fractures, such as that of the ulnar styloid or navicular.

7. Small fragments of bone in the neighbourhood of osteo-arthritic joints.

8. Last traces of the epiphyseal lines, and ununited secondary centres persisting (Fig 708.)



FIG. 29. Old ununited fracture of the ulnar styloid, showing well the thin layer of compact bone over the fractured surfaces, and the smoothness of the surfaces distinguishing it from any recent fracture. A malunited Colles's fracture.

Careful history and examination of the films will exclude such lesions. Old fractures and sesamoid bones and accessory bones will show a rounded-off margin, and a layer of condensed bone across the supposedly fractured surface. In recent fractures the fracture line is irregular, often soft or blurred in cancellous bone, or sharp and clear in compact bone.

NOTE. Among casualty officers errors may be grouped as follows :—

	Per cent
1. Ignorance. Fracture seen, significance not recognised	10
2. Over-anxiety. Fracture diagnosed when none present	5
3. Failure to assess clinical signs and X-ray case	20
4. Failure to see fracture in films	15
5. Fracture diagnosed on account of presence of old ununited fracture or other pathology	30
6. Failure to take adequate X-rays	15
7. Administrative errors, patients departing without X-rays, etc.	5

Supplementary Radiographs

The use of certain additional films may be of assistance in coming to a definite opinion in doubtful cases. These are summarised below.

1. The oblique view. The value of this in supplementing the usual antero-posterior and lateral views has been emphasised for the navicular. It is useful in other situations, either to show up a doubtful fissure by getting the central ray of the tube to coincide with the fracture, or by providing a new view point to clear up a doubtful fracture (*e.g.*, a fracture of an articular process in the spine).

2. Repeated films after the passage of a short time. This takes advantage of secondary changes in the fracture line, which may make it more distinct.

3. Radiographs of the opposite side where epiphyseal lines are suspect, or in unusual fractures

4. Radiographs under strain. Occasionally of value where there is doubt of the firmness of union of long bones or the repair of ligaments The bone may show bending or displacement under strain.

5. Radiographs in the position of deformity. This is chiefly of value in detecting the rupture of ligaments in the vicinity of joints, but may be useful in determining the presence of diastasis, or the severity of a sprain fracture.

6. Arthrography. Has little place in the treatment of fractures, but may be of value in the diagnosis of difficult lesions of the knee or ankle, or ruptures of the capsule of the shoulder.

7. Tomography. This is of little value in superficial bones, but may be helpful in doubtful fractures of the spine.

FURTHER READING

Joint Mobility

CAVE and ROBERTS. "A Method for Measuring and Recording Joint Function," *J. Bone and Joint Surg.*, 1936, 18, 455. (Forms the introductory chapter to "Scudder." Outlines the normal joint movements and their range and nomenclature.)

Radiology

CLARK, K. "Positioning in Radiography" London, Wm Heinemann 7th Edition, 1956

BRAILSFORD, J. F. "The Radiology of Bones and Joints" London, J. & A Churchill, 5th Edition, 1953.

LYSHOLM, E. "Apparatus and Technique for the Roentgen Examination of the Skull." Stockholm, 1931.

CHAPTER IV

GENERAL PRINCIPLES OF TREATMENT

With succeeding years the principles of treatment of fractures have altered very little. Reduction, retention and re-education have remained the three R's of the traumatic surgeon, but at different periods a different weight has been attached to the importance of each phase. Reduction has always been regarded as necessary except in certain fractures, and some old treatises on the subject contain much elaborate apparatus for the purpose, some crudely anticipating the apparatus now used. Retention and re-education, however, have had a see-saw existence through surgical history instead of balancing one another. In the years before Championnière, the insistence on absolute fixation of the limb resulted in many stiff joints, a complication from which we are not entirely free to-day. Championnière substituted early movements and massage for this, and improved the results, so that till recently the removal of splints and massage was an essential part of the treatment. The importance of early and complete fixation in obtaining firm union has not been lost sight of, and it has been the struggle to unite the advantages of both methods, which has resulted in modern developments. While the battle of theory has had its usual ups and downs that of technique has shown a steady advance, and open operation and internal fixation, or skeletal traction with or without plaster, has enabled a better balance between retention and re-education to be struck and maintained. To this has been added the more accurate reduction and control of retention made possible by X-rays

We may summarise the principles of treatment thus :

Reduction. Immediate and accurate.

Retention Continuous and absolute.

Re-education. Active, early, and persistent.

We can now proceed to a fuller discussion of the principles which underlie reduction. This should not be carried out till shock has subsided and adequate retentive apparatus is at hand. Before this is possible there is a period in which the patient is in unskilled hands and further damage is liable to occur. The aim of first-aid treatment is to prevent this by the use of whatever is available to prevent movement and soiling of the injured limb, and combat the occurrence of shock. The importance of this emergency treatment

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FURTHER READING

Joint Mobility

Cave and Roberts. "A Method for Measuring and Recording Joint Function," *J. Bone and Joint Surg.*, 1936, **18**, 455. (Forms the introductory chapter to "Scudder" Outlines the normal joint movements and their range and nomenclature)

Radiology

Clark, K. "Positioning in Radiography." London, Wm. Heinemann. 7th Edition, 1956.

Brailsford, J. F. "The Radiology of Bones and Joints." London, J. & A. Churchill, 5th Edition, 1953.

Lysholm, E. "Apparatus and Technique for the Roentgen Examination of the Skull." Stockholm, 1931.

of the knee relaxes the gastrocnemius and enables shortening of the leg to be pulled out, at the same time the muscles are slightly increased in bulk, and it is difficult to apply a plaster with a tight-fitting upper end. For the first plaster in which weight-bearing is not as a rule desired, this is unimportant.

In order to place traction on any limb arrangements must be made for counter-traction. In general these consist of placing a sling around the body or limb being pulled upon, and attaching this to a hook in the wall, so that it will exert a pull in the opposite direction. In other cases the body may be used as a fixed point against which the limb may be extended, such as the extension of a femur against a perineal bar on the orthopædic table. In certain cases of skeletal traction accurate control may only be obtainable by the use of a second pin or Kirschner wire for counter-traction. Where continuous traction is used the body is used for counter-traction, by elevating the bed.

In reduction one has to correct :

1 Shortening. By traction.

2 Angulation. By the direction of traction and manipulation.

3 Lateral displacement. Traction by increasing the tension in the tissues exerts some lateral pressure, but manipulation is most important.

4. Rotation. By correcting the position of the limb.

Immediate reduction has the following advantages :

1. It reduces the size of the hæmatoma.
2. It limits and reduces reactionary swelling.
3 It removes pressure from soft parts, particularly blood vessels and skin.
4. It relieves the patient of pain.
5. It can usually be more easily accomplished as the bony points are not obscured by swelling, and the tissues are laxer.

Delayed reduction may be necessary for the following reasons :

1 The presence of shock.
2. The necessity for the treatment of associated injuries first
3. The presence of infection.
4 The absence of retentive apparatus
5 Because the method of retention combines slow reduction of the fracture by traction.

There are only four methods of reduction to choose from, each suitable to individual cases, and they may be combined to meet various difficulties.

was shown during the Great War, when the application of the Thomas splint on the field to injuries of the leg reduced the mortality for such injuries from 80 to 15 per cent. The combating of shock falls more to the province of the doctor, and of primary importance is the relief of pain. Morphia is unsurpassed for this purpose in relieving the local pain, and the general psychological disturbance. Most effective in combating local pain is the injection of local anæsthetic into the fracture site. This is often a preliminary treatment and will be described in detail later on, but its effect on shock is startlingly satisfactory in many cases. Heat externally by a cradle or the use of hot-water bottles, and a hot drink of coffee, are other sound measures. The restoration of blood loss by transfusion is also important. Shock and its treatment are discussed more fully in Chapter V.

Reduction

The forces producing or maintaining displacement which may have to be overcome are :

1. Gravity. This produces angulation as a rule.
2. The injury itself, if impacted or greenstick.
3. The force producing the injury.
4. The activities of assistants aiding the injured man.
5. Muscle spasm, producing shortening and angulation.

We will not discuss gravity further except to say that its effects must be constantly watched for. To avoid its effect in fractures of the leg Watson Jones has designed an ingenious extension apparatus for use with the leg dependant. In the more usual methods the tension needed to overcome shortening also overcomes sagging.

Disimpaction of the fracture is an essential to complete reposition of the fragments, and must be made before reduction is attempted. In certain cases, such as fracture of the upper end of the humerus, it may be unwise to disimpact.

The most important force to be overcome in correcting the displacement is muscle spasm. This may be overcome in various ways :

1. Slow traction without an anæsthetic.
2. A general anæsthetic.
3. A local anæsthetic The spasm being reflex it is partly abolished by the relief of pain, but some muscle tone will remain particularly in the lower limb. It is usually sufficiently abolished for traction to be successful if maintained long enough, *i.e.*, two to three minutes. The length of time necessary for traction is overestimated in most books.
4. The relaxation of the muscles by positioning he tlimb. Flexion

above together with the further disability that lateral movements can occur as there are no interlocking fixed points to prevent it. Treatment by traction must be supplemented by some form of lateral support, from a splint or from plaster of Paris. If operative treatment is contemplated, a plate, longer than the length of the comminuted fragments must be employed.

Transverse fractures. If the ends can be maintained opposite one another, or reduced so that they engage, there is no fear of shortening. Angulation and rotation only need be feared, and these are best controlled by plaster. In the thigh the muscle bulk makes lateral control difficult, and extension must be used to supplement it. The average transverse fracture is best treated by manipulation and plaster, though some, such as the femur, may require operative fixation.

Retention will also depend on the limb involved, whether upper or lower. In the arm shortening is unimportant, but angulation is important. In the leg shortening and angulation are both very important. Oblique fractures of the leg cannot be allowed to bear weight early owing to the risk of deformity due to the body weight. A transverse fracture can be allowed to bear weight earlier as shortening cannot occur, and lateral control is easier to maintain. Oblique fractures tend to unite more rapidly than transverse fractures, and fractures near the ends of the bones sooner than fractures in the mid-shaft, which influences the time it is necessary to maintain retention.

Traction. Emphasis must be laid on the fact that the primary *purpose of traction is reduction, and not retention.* It is now recognised that skeletal traction has increased the number of ununited fractures This statement indicates that the great forces available when using skeletal traction have been misapplied, and used for retention or over reduction. Correctly used, skeletal traction is the greatest single blessing provided by the beneficence of "modern technique." It is appropriate here to outline the relative merits of skin and skeletal traction.

DISADVANTAGES OF SKIN TRACTION.

1. It gives slowly, and so requires repeated renewals.
2. It is painful.
3. It produces a crop of skin pustules on certain skins.
4. It covers a large area of skin and so prevents inspection and cannot be applied over abrasions.
5. It is inaccurate in alignment, and cannot be used to control rotatory displacements.
6. It will only stand a limited weight. In children in whom the skin area relative to the weight is larger this may be unimportant. (See Bryant's method, p. 514.)

Manipulation.
Wedging the plaster.
Continuous traction.
Operative methods.

The choice of method and its application to individual fractures is the theme of the special section of this book.

Retention

The demands made on retentive apparatus are as follows :

1. That it should produce absolute fixation.
2. That it should limit movement of the undamaged structures to a minimal degree.
3. That it should allow the examination of wounds by vision, and of the bones by X-rays.
4. That it should be adaptable to various lesions, and, if possible, to various sites.

These demands are best fulfilled by plaster of Paris, which is being used in increasing amounts in modern methods. Certain fractures require other splintage to control them, and the most important point in determining this is the type of fracture, whether it is oblique, transverse, or comminuted.

Helical or spiral fractures. Here the deforming force has been a rotatory one. The displacement in a lateral direction is minimal. On the other hand there is nothing to counteract the pull of muscles tending to shorten the limb, and this must be overcome by continuous traction or fixed distraction. There is also some risk of angulation, even in the case of fracture of the tibia with the fibula intact. The shape of the fractured surfaces in a helical fracture often render perfect reduction by ordinary means impossible, if there is any displacement Perfect reduction and retention are easily accomplished by one or two screws which combine the insertion of a foreign body of minimal size with the attainment of sufficient stability for early exercises

Oblique and half oblique—transverse fractures. These two types of fracture have already been shown (Fig. 7) to be variants of the transverse fracture due to bending violence. The third variant is the " butterfly " fracture in which a single triangular comminuted fragment is produced All three types show a tendency to shortening and angulation. They are readily, but not perfectly, reduced by traction and manipulation, and retained by traction or distraction. All three lend themselves to fixation with a single or double screw or plating.

Comminuted fractures. These suffer the disadvantage mentioned

following accidents. The vast majority of accidents are industrial, or affect the industrial machine indirectly. In a nation on a war footing it becomes still more important that every available man-hour of labour should be used, and the problems of rehabilitation have therefore been studied more intently and under better statistical conditions in the last few years. The problem is a threefold one :—

1. Physical medicine : the scientific application of measures to restore physical fitness ;

2. Psychological : the problem of obtaining the patient's co-operation and stimulating the desire to return to normal life ;

3. Sociological, (*a*) as it affects the patient : relief from personal financial worries during treatment and a guarantee of employment on recovery ; (*b*) as it affects the community : financing and organising a rehabilitation centre for the area.

Rehabilitation in a hospital in its widest sense embraces every activity and relationship of the patient while undergoing treatment. The stimulating atmosphere of the ward, the relief of the patient's mental anxieties, the quality and regularity of his meals, and the occupations of his spare time are as much the concern of the Rehabilitation Officer, and the patient's own doctor, as the efficiency of the massage staff, the quality of his ward sisters, the provision of adequate exercise space, and the mental drive of the physical training instructor. All must be co-ordinated into a harmonious whole, in which the confidence of the patient is echoed in the confidence of those around him and his instinctive desire to recover is fostered and encouraged by all means.

Rehabilitation outside the hospital is often left to the Almoner, but is as much the concern of the surgeon as his ward round. The atmosphere to which the patient returns on discharge from in-patient treatment, or in which he has to spend his time during out-patient treatment, may be quite inimical to his morale, and undo any good done by a short attendance at the hospital waiting to have something " done." It is the conviction that he must do something for himself, that in fact it is almost entirely what he does himself, and not what is done for him, which is important, that must be driven home.

The complexity of the problem and the complete absorption of the patient's time, interest and energy which good rehabilitation demands, makes the combination of acute traumatic surgery and rehabilitation in the one ward difficult. High spirits and energy should not be restrained by a seriously ill case. Rehabilitation commences in the acute ward, but graduates to a stage when the atmosphere of the ward is unsatisfactory for both the bed patient

ADVANTAGES OF SKELETAL TRACTION.

1. It is accurate and non-slipping.
2. It is painless.
3. It leaves the skin free for inspection, or the application of plaster.
4. It will take great weights.
5. Rotatory deformities can be corrected by it.
6. Its incorporation in the plaster may aid in retention.

DISADVANTAGES OF SKELETAL TRACTION.

1. The entry and exit wounds of the wire may become infected leading to osteomyelitis. In practice this is rare if care is taken to see that the wire does not rotate in its bed and the skin around the puncture wounds is supported by light pressure to prevent movement and soiling.

2. The method allows long-continued traction through joints to be made, with disastrous results to the joint, whose ligaments are stretched, and relaxation is followed by an effusion and subsequent stiffness. Traction should never be made through joints for longer than two to three weeks, and never with great weight.

3. Over-reduction and non-union are the results of misuse.

4. It cannot be used in young children, owing to the risks of perforating the growing ends of bones, and the fact that the wire cuts out of the soft bone.

Re-education

This is perhaps the most important feature of modern methods. The reduction and retention of a Colles's fracture in an old woman may be perfect, but unless she is instructed to move her fingers and shoulder, and care is taken to see that she does it, she may develop permanent stiffness of the hand and shoulder as a result. The same applies to fractures elsewhere. The exercise of the patient and his co-operation in such exercises is extremely important, and with experience it is quite possible to forecast the duration of a patient's stay in a fracture clinic from his mental make-up. An active and interested patient who is not afraid of a little discomfort and "prepared to try anything once" will recover the functional use of the limb in almost half the time it takes a nervous, melancholy and apprehensive patient. The engendering of interest, the encouragement of the patient, and the development of an attitude of confidence is the duty of the doctor. One of the best methods of achieving this is the spirit of competition aroused by competitive exercises with other patients with the same lesion. The association of a fracture clinic with a cheerful gymnasium in which the patient can exercise and be exercised is an essential for good results.

Rehabilitation

It has become clear in recent years that an academic interest in re-education alone is not sufficient in an industrialised community to give the maximum return of useful labour in the minimum time

interests are restricted and can be introduced in many ways. The occupational therapist may be able to devote some time to patients not specifically requiring her attention. Adequate library facilities, the organisation of educational groups, cinema shows in the wards and other entertainments are of great value. More important than entertainment given is entertainment made by the men themselves. Discussion groups, small concert performances, or the production of a ward column in the hospital news-sheet, may help. Not to be forgotten are the various routine jobs of the ward suitable for untrained workers, and which, being actually of use, may be more stimulating to the right person than many cleverly contrived but useless amusements.

REHABILITATION IN THE SPECIAL CENTRE. The Centre may be provided by the hospital gymnasium with some ancillary rooms, but is preferably a small separate institution of around 150 beds. Here all the modern methods of physical re-development are available. Patients may be living in the centre, or attend daily, but the importance of a fully occupied day at the centre must be stressed. The patient must do a full-time course. If only trained for a few hours a day his return to his ordinary way of life for the rest of the twenty-four hours may effectively undo any mental or physical benefit achieved.

The distribution of the men's time at such a centre is important and needs considerable clerical assistance. Each man should be given a weekly time-table of the classes to be attended and his improvement and graduation from class to class should be recorded. The following departments of the centre should be fully harmonised.

1. *Physiotherapy.* This is useful in starting off patients with stiff joints and limbs, and particularly in the care of cases of nerve injury. It is valuable, but insistence must be made on active voluntary exercises, and the patient made to realise that physiotherapy is only to facilitate this.

For instance, the quadriceps can be best exercised by voluntary contraction which should be taught in preference to the use of Faradism The vastus medialis, however, can contract only if the knee will finally extend, and screw home, and this condition is not present in the early phases of treatment of most cases of knee injury. It follows that Faradism should be applied in the early stages to the vastus medialis only and the rest of the muscle exercised by voluntary quadriceps contraction. The value of physiotherapy radiant heat, short wave therapy, and diathermy is chiefly to promote relaxation and increased blood supply, which allows an increased range of voluntary movement and promotes absorption of exudates.

and the ambulant. Further, the routine of the ward conflicts with the routine of rehabilitation exercises and for these reasons it is desirable to separate them. If they cannot be sent to a specially equipped centre they can be segregated in another part of the hospital to which they can graduate as they recover. The most satisfactory results are achieved by a country rehabilitation centre

The problems of the centre not only include those of staffing, space, feeding and therapy, but the problem of the patient himself. It is still the conviction of many that they go to hospital to be made well, and not to make themselves well. The attainment of the patient's confident belief that the methods recommended are for his own benefit is of the utmost importance. Nothing can be done to rehabilitate a man without his co-operation, and to encourage and develop this is the first care of the staff.

REHABILITATION IN THE WARDS. We concern ourselves here particularly with the patients whose confinement to bed limits their range of activities. As soon as is appropriate they are sent to the Rehabilitation Centre, as the first big step in their recovery. The ward morale is dependent on everyone, doctors, sisters, nurses, and patients alike, but its tone is set from the top. The tidy ward, the regular routine, the firm convictions of the staff, are breathed in from the moment of the patient's arrival. No more responsive wards are to be found in a hospital than those of a Fracture Unit, where the mental tone of the patient is in the vast majority of patients unimpaired

Physical therapy in the wards fall into two compartments :—

(*a*) Special exercises, *e.g* , to fingers and toes, shoulder and knee of a limb immobilised by treatment.

(*b*) General exercises to the remainder of the body free of restraint, which can be undertaken by the ward as a whole, or in convenient groups, *e.g* , upper limb injuries, lower limb injuries

In the first group there is considerable scope for inventive imagination in the design of retentive apparatus which allows the maximum freedom, and the invention of exercises to take full advantage of this A special orderly of suitable personality should be trained in these exercises and spend most of his time in the ward instructing and encouraging patients. The patients should be reminded by a two-hourly bell that they are expected to devote the next ten minutes to their exercises The more general class exercises may be carried out twice a day.

Occupational therapy. In many cases this may begin in the ward. Its three aspects are discussed more fully under therapy at the Rehabilitation Centre.

Recreational therapy. This is important in the ward where

cluded in any complete scheme for rehabilitation. These include dancing, dramatics, debating, formation of small orchestras, publication of a news-sheet and the like.

Time cannot be spent here on functional therapy, where great ingenuity can be used in designing exercises to develop specific muscles, or movements. In particular, the employment of the hands in fretwork, weaving, basket work, knotting, leather work, carpentry, etc., is of great importance. The large representation of the hand in the cortex makes it inevitable that many paths of association must be rendered useless in any serious injury, and these can only be replaced by fresh ones by constant application. Suppleness and muscle tone are improved at the same time. Care must be taken not to over-emphasise the production of entertaining but useless objects. This may undo the good effect of activity, by accenting the inability of the patient to do normal work. The production of a small quantity of material of real use on an assembly bench, has great psychological advantages, as well as practical ones, and for this reason the Sheltered Workshop is particularly valuable.

The Sheltered Workshop

Pre-vocational therapy is of extreme importance in an industrialised community. It demands the development of a close relationship with the employer and the Industrial Medical Officer. Centres have been developed for single industries, in particular mining, where the demands made by the work on the individual are extremely variable, and considerable experience is necessary of the various special jobs inside the industry to return men to suitable employment. In smaller and more specialised industries the industry itself has set apart floor space where its employees can return to work under less exacting conditions and harden themselves for their old job or adapt themselves to new ones. The light engineering workshop is particularly suitable for a graded return to work. Machine tools can be found or adapted to a wide variety of movements of hand or arm, and adjusted to exercise particular muscles. All three variations in muscular activity can be easily achieved, and the stimulation of producing something really useful may do much for the patient's morale.

Exercises in relation to Fractures

It must be constantly borne in mind that the active movement of the limb by the patient for a few minutes is worth hours of massage. The massage department, unless specially instructed, often lulls the patient into a false sense of security, in which, feeling that something is being done for him, he will not do much for himself. The importance of this must be explained to the patient and the massage staff. A few specimen tables of exercises follow as a guide as to what can be done

2. *Physical training instruction.* This is probably the most important single element in rehabilitation, increasing general bodily well-being as well as the muscular power of the affected limb. Classes may be grouped in varying ways, according to the part of the body affected : (*a*) Upper limb injuries ; (*b*) Lower limb injuries ; (*c*) Spinal injuries ; (*d*) Special cases ; or according to the severity of the exercises. Obviously the type of cases passing through the centre will govern the arrangement of classes. The fundamental factors governing the progress of the patient is his response to exercises which make increasing demands on his strength Exercises may be increased in

(*a*) Range of movement.
(*b*) Strength of resistance to effort.
(*c*) Duration of activity.

These three variables are employed in varying proportions to suit each case firstly with regard to general physique, and again with regard to each joint being specially exercised. All activities are alternated with periods of rest and relaxation. Thus in exercising a joint it is not sufficient for the limb merely to come to the end of its range of movement and then retrace its movement under continuous muscle tension. At each end of the range of motion there should be a dead spot, where the resistance is removed entirely, and a period of relaxation given. In pulley and weight exercises this can be arranged easily by suitable knots in the cords, or the introduction of stops against which the weight or limb comes to rest.

The organisation of outdoor and indoor games which add the zest of the competitive spirit to exercises is usually the province of the P.T instructor Apart from providing a fresh and pleasant way of taking exercise, they have valuable sociological aspects.

3. *Occupational therapy* This takes three forms :—

(*a*) Diversional therapy To maintain patients' interest during tedious periods, and to improve morale and allay anxiety.
(*b*) Functional therapy Activities specially designed to exercise certain joints and muscles.
(*c*) Pre-vocational therapy Preparation of the disabled for return to his old occupation, or the selection and training for a suitable job if that is out of the question.

It will be appreciated that diversional therapy is particularly needed for the recumbent patient, but that organised games which may be considered a part of P T may also come under this heading. There are a wide variety of communal occupations which for their sociological and character developing potentialities should be in-

When the movements are only limited by a forearm plaster, class exercises can be carried out on the usual lines.

Arms forward raise, hands on shoulders, hands out.
Arms lateral raise, hands on shoulders, hands out.
Arms upward raise, hands on shoulders, hands upward raise.

And to these very many variations of free shoulder movements may be added, such as free arm swinging, alternate arm swinging, and combinations with trunk exercises

In special cases many special exercises may be devised, always remembering that encouraging the patient to use his muscles against the action of gravity, or the pull of adhesions, is as a rule better than pulley and rod exercises in which excessive movement may be forced, and so produce reactionary effusion.

Specimen Scheme for Cases in Plaster Jackets

Head.

Prone head raising. (Extension.)
Supine head raising (Flexion.)
Rotation.
Lateral flexion.

Arm.

Exercises above possible, worked in with a Colles's fracture class.

Leg.

Supine. Straight leg raising.
Alternate leg raising.
Knee flexion
Shadow cycling.

Standing. Knee flexion.
Leg forward raise.
Knee forward raise. Leg extend.
Marching. Goose step.
Forward bending.
Lateral bending.

Spine.

Lying supine on table Legs raise, hands grasp table Body raise. Legs held, with arms to sides, with arms extended.
Lying supine. Back over edge of the table. Legs held. Hyper-extension of the spine, body raising.
Marching with a book or weight on the head.
Balance walking

Rehabilitation Centres

In dealing with many patients of the working class an awkward intermediary period is encountered in which the patient, though fit for light work, is not fit for his original employment, and as the employer wants the patient back fully fit, or not back at all, it has been necessary to organise further assistance in the form of [illegible]

let him carry hods of bricks or wheel loaded barrows, or climb ladders, or dig, or otherwise employ himself at the job he used to have. Under suitable leadership these centres are not only places where sound social work can be done, but send many a man back to work in a far shorter time than would otherwise be the case, and save many another from being classed as "unemployable"

Exercises for Recumbent Cases

These exercises are gone through twice daily by all cases, and more often by patients on advanced exercises

Breathing.
- Half lying breathing Deep inspiration. Deep expiration.
- Half lying side bending, to L. to R., with breathing.
- Half lying, two arm side raising, with inspiration.
- Half lying, hands on hips, inspiration and expiration.

Neck
- Head raising.
- Head rotation
- Lateral flexion of the neck.

Arms.
- Lying. Straight arm raising. (Abduction)
  - Straight arm vertical raising.
- Elbow flexion. Abducted arm.
  - Vertically held arm.

Trunk.
- Lying Trunk rotation, with arm and shoulder movement, arm being swung over the side of the bed.
  - Trunk rotation with head and shoulder lifting, the arm being held to the side.
  - Shoulder lifting.
  - Back arching.
- Sitting. Reach long sitting, forward bending, touching alternate ankles
  - Arm circle swinging with ankle grasp.

Uninjured leg.
- Straight leg raising.
- Hip flexion
- Knee flexion
- Quadriceps drill.
- Foot Dorsi- and plantar-flexion.
  - Inversion and eversion
  - Circumduction
- Toe flexion and extension

Injured limb
- As many of the above exercises are carried out as is possible without disturbing the retention This is generally limited to ankle and toe exercises, with the later addition of hip and knee movements.

Ambulant patients Similar exercise in the standing and sitting positions are given, with considerable enlargement, including the full range of movement of every unfixed joint.

Arm Exercises

Exercises are limited by the extent of the plaster. Shoulder movements are possible with the arm and forearm plaster, and in all cases the full range of finger movements outlined in Chapter XXII should be carried out With the elbow immobilised the following exercises can be carried out

- Abduction.
- Forward swing. (Flexion)
- Backward swing. (Extension)
- Arm behind head. (External rotation
- Arm behind back. (Internal rotation)

CHAPTER V

THE IMMEDIATE COMPLICATIONS OF FRACTURES

General

1. Shock.
2. Traumatic fever.
3. Hæmorrhage. (See injuries to vessels.)
4. Fat embolism.
5. Delirium.
6. Bronchopneumonia.
7. The crush syndrome.

Local, Due to injury to structures surrounding the bone.

8. Injury to nerves. (Crushing, contusion, concussion, stretching, division.)
9. Injury to vessels. (Arteries and veins.)
10. Injuries to joints.
11. Injuries to viscera.
12. Injuries to soft tissues, muscles, tendons, and skin. Discussed under compound fractures.

Shock. Shock is a condition of depressed vital functions which supervenes on injury after a variable period. Its ætiology is not yet entirely clear, but one important established factor is a general anoxæmia due to disturbed respiratory and circulatory functions. The degree of shock is governed more by the amount of soft tissue damage than the site of fracture.

"Shock" has three components. First, pain: this is the immediate "shock" of an accident as understood by the public. It can be overcome either by local analgesia, regional analgesia, or (as a rule most conveniently) by analgesia with opiates such as morphia, omnopon or pethidine. Second, there is blood loss or "oligæmic shock"; this is the most important component, and it is with reversible, primary, oligæmic, shock we are chiefly concerned. Third, if oligæmic shock be inadequately treated tissue anoxia develops and leads to the development of irreversible or secondary shock from which recovery is difficult. Infection may play a part in the conversion of primary to secondary shock.

Shock varies from individual to individual. Highly strung people are more susceptible to the condition. The general health of the patient before the accident, and whether or not he was tired out or hungry also affects his susceptibility. As the pathology of the condition is not yet clear, it is most convenient to discuss shock under the clinical features.

SPECIMEN TIME TABLE OF A SPECIAL REHABILITATION CENTRE

Hour.	Occupation.
0730	Reveille.
0800.	Breakfast.
0830.	Bed exercises for recumbent patients.
	Non-weight-bearing exercises attended by weight-bearing patients.
0900	Individual special exercises.
	Class gymnastic games.
	Prevocational Therapy.
1000.	Break. Hot drink.
1030.	Parade Inspection. Complaints. Suggestions.
1045.	General Physical Training.
1130	Games Non-organised Ping-pong, darts, billiards, etc.
	Walk for progressing patients.
	Run, for hardening patients.
1230.	Lunch Rest period for new and weaker patients
1400.	Parade.
	Bed exercises for recumbent patients.
	Organised games.
1500.	Non-weight-bearing } P.T Classes, separate. Weight-bearing }
1530	Rest period
1545.	Tea
1630.	Quadriceps Class.
	Occupational Therapy.
	Diversional Therapy.
1900.	Free time.
1900	Supper.
1945	Parade. Night roll.
2000.	Entertainment. Concert, cinema, ping-pong tournament, housey-housey debate, lecture, etc.
2130	Hot drink
2200	Lights out.

FURTHER READING

British Medical Association. "Report of Committee on Fractures." London, February, 1935.

PERKINS, G. "Rest *versus* Activity in the Treatment of a Fracture," *Lancet*, 1947, 1, 49–54.

COLSON, J. H C. "The Rehabilitation of the Injured," Vols. 1 and 2, 1949. Castle & Co , London

COLSON, J. H C. "Postural and Relaxation Training." Wm. Heinemann, London, 1956.

causes, or combinations of causes (Fig. 30). As indicated under treatment, it should be rigorously combated.

4. *Pulse rate.* This is extremely variable. Of most importance is the general impression given by the pulse, where clinical acumen sums up variations in vascular tone, circulating volume, blood pressure and pulse pressure. The whole tone of the vascular tree is thus sampled by the index finger. A rapid fluttering pulse is serious, and is usually combined with a low blood pressure, as recovery sets in the pulse slows and the blood pressure rises. Exceptional cases with a slow pulse and low blood pressure are met with.

5. *Blood pressure.* The observation of the systolic and diastolic pressure and of the difference between them (pulse pressure) is perhaps the most useful single guide to the condition of the patient. It has the advantages of being readily determined at the bedside and easily recorded. Nevertheless, taken alone, it may be a source of error, as in the early stages of shock, (*i.e.*, within two hours) the blood pressure may be raised, and rare cases are met with in which it is high throughout the whole clinical course. With the development of the full picture of shock (delayed or secondary shock) the blood pressure falls and may be impossible to record. As a general level below which the condition becomes more and more serious, and above which the prognosis is more and more hopeful, the figure of 90 mm. may be remembered. No case should be taken to the theatre with a blood pressure below this level unless circumstances force it. Pulse pressure is difficult to determine in the shocked owing to the undefined diastolic sounds. Its easy determination and normal level (45 mm.) is a valuable sign of recovery.

6. *Hæmorrhage, and Transfusion.* Primary oligæmic shock is always due to reduction in blood volume because of blood loss. Overt blood loss is easily recognised, bleeding into the tissues less so. If tissue is seriously damaged, blood is extravasated into it; and this blood is lost to the circulation even though it remains in the body. A convenient measure of tissue damage may be obtained by comparing the volume of the injured area with the fist of the sufferer—one fist corresponds to about $\frac{1}{50}$ blood volume. Transfusion is rarely necessary if the damaged muscle is less than three fists volume; between three and seven fists transfusion is desirable and usually necessary, and over seven fists essential. Some allowances must be made for variation in the extravasated blood which constitutes the swelling around the fracture.

If blood loss is small the body can recover from it spontaneously: water passes from the cells and interstitial tissue into the blood, and protein slowly enters the blood stream so that in twelve to forty-eight hours the blood volume has been restored, though the

1. *Pain.* Painful stimulation of a peripheral nerve will produce a fall in the blood pressure, and this will aid the general reduced oxygenation of the tissues which is a principal factor in the condition. In this connection it is to be noted that great excitement induces a relative anæsthesia. Not till the excitement passes off does shock supervene with the onset of the pain.

The most generally useful anodyne will be found to be morphia given in ¼-grain doses. Local anæsthesia into the fracture is a valuable aid. Early first aid fixation of the fracture is also important.

2. *Temperature.* A low temperature is an invariable accompaniment of any degree of shock.

Some have advised that the shocked patient should be warmed until his skin becomes warm. One must not chill him, but it is unwise to apply heat. If as a result of warming, the peripheral vessels dilate, then either the blood pressure will fall still more or vasoconstriction of the viscera will occur—both disadvantageous to the body If the peripheral vessels fail to dilate, then local metabolism may be increased, leading to the production of toxic metabolites, or a local rise in temperature sufficient to damage the tissue may occur. Blood flow increases in the skin under a hot water bottle because the blood has to take the heat away to avoid local overheating : when the circulation is virtually stationary, a hot water bottle may cause severe burns. Shocked patients should not be warmed until their blood volume is large enough to release the peripheral vasoconstriction.

3. *Colour.* This is an unreliable guide to the patient's condition, except that satisfactory return of colour may be regarded as a sign of recovery. Pallor is due to peripheral vasoconstriction, but it is difficult to determine whether this is of central origin, in an endeavour to maintain blood pressure and volume, or peripheral spasms due to heat loss and external cold Cyanosis, indicating anoxæmia, is significant of the severity of the condition, but may be due to many

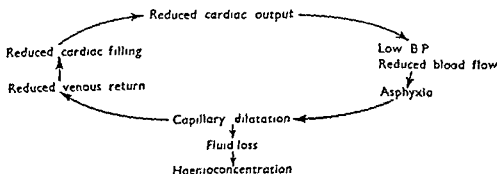


FIG. 30. The vicious circle of shock.

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red cells are less numerous and the serum protein less concentrated. If the loss is too great for this to occur, or if the patient requires immediate active treatment, the blood lost must be replaced, preferably by blood, failing that by plasma, serum, or dextran.

Transfusion in oligæmic shock is designed to maintain the circulating blood volume and has nothing to do with anæmia. If from a normal subject blood is progressively removed, the body compensates for it : the principal compensation is afforded by peripheral vasoconstriction, so that because the blood stream no longer carries heat to it, the body surface becomes cold and clammy. The treatment of oligæmic shock is to raise the blood volume to such a level that vasoconstriction is overcome.

Indications for Transfusion

It is rarely possible directly to estimate the blood lost, nor the circulating blood volume ; one may guess, using the rule of the fist, one's experience of comparable injuries, and the degree of peripheral vasoconstriction as judged by the coldness, clamminess and pallor of the skin. Two other factors may be considered : blood pressure and pulse rate. One can never know the previous range in any particular patient, but it is reasonable to assume that since the normal blood pressure ranges between 110 and 130 systolic and 70 to 90 diastolic, in an injured person figures below this range indicate shock. A blood pressure below 80 mm. systolic is an indication for early blood transfusion ; one of 70 mm. indicates some urgency, while a systolic blood pressure of 60 mm. or less requires immediate transfusion with plasma, serum or dextran to maintain the circulation until blood can be obtained : in such cases, blood must be demanded urgently, and one cannot afford to wait for the four-hour period demanded by serologists for cross matching. In some older persons, hypertension is present, and in such patients, loss of blood may have lowered the systolic pressure 40 to 60 mm. even though it is found to be 140 to 170 mm. These also need transfusion.

Healthy persons have pulse rates between 65 and 80, which can rise to 100 under the influence of emotion. A pulse rate exceeding 100 is the usual accompaniment of blood loss sufficiently severe to warrant transfusion this is a very useful guide to transfusion, especially for hypertensive patients, the transfusion being continued until the pulse rate falls below 100

The Choice of Fluids for Transfusion

Whole blood is probably the ideal fluid, but it has several disadvantages : first, the need for blood grouping and cross matching to avoid hæmolytic reactions and sensitisation to the Rhesus factor .

second, the risk of conveying disease such as hepatitis ; and third, it is sometimes difficult to obtain. Blood cross-matched in the way advised by experts in blood serology can be obtained only after several hours, and emergency cross-grouping carries a risk of incompatibility which may lie between 1 in 1,000 and 1 in 2,000. Hepatitis occurs in one of every 100 recipients, and carries a death rate around 20 per cent. Plasma or serum nowadays is prepared in small batches containing plasma from about ten donors, and carries the same risk of hepatitis as whole blood, but since they require no cross-matching, they can be used before blood becomes available. Dextran carries no risk of hepatitis, and only the slightest risk of severe non-specific reactions : it is replacing plasma for many purposes, particularly in the early treatment of oligæmic shock ; but it is unwise to use more than 1,500 ml. (three bottles) at one time, because the hæmodilution it produces would produce appreciable anæmia, and little is known of the effect of high concentrations of dextran *in vivo*. Blood samples for grouping and cross-matching should be taken before dextran is given, because dextran causes rouleau formation which can be confused with agglutination : the cross-matching of blood with serum containing dextran is a slow procedure requiring at least two hours, even when the presence of dextran is known : it requires four hours if the pathologist has to discover its presence.

7. *Toxæmia.* The role of tissue products of the histamine type in shock is still debated. The recent elucidation of the crush syndrome shows the important effect of myohæmoglobin in disturbing physiology. It is probable that histamine products plays a certain part in the production of shock but that the vicious circle to which they contribute, gains its chief momentum from its own interactions (Fig. 30).

Decision as to operation. Nothing may be more difficult to determine than the right moment for operation. As a general rule operations are carried out early, in the recovery phase from primary shock, before secondary shock develops, or after secondary shock has been overcome in part at least by restorative measures. The first period occurs within the first three hours of injury. Appropriate measures to overcome the combined surgical shock and wound shock which will follow are commenced at once, without waiting for specific indications. Plasma and blood are administered on the table from the start of the operation. The second period of operability cannot be confined so easily to time limits. The ideal moment varies from case to case, sometimes it is early, *i.e.*, within five hours, more often late. It is noteworthy that there has been an increasing tendency to postpone interference in seriously shocked cases, so that fifteen to twenty hours' rest and resuscitation may be given.

Traumatic fever. Owing to the absorption of the products of autolysed blood from the hæmatoma the temperature may rise as much as 2° (100·8), very rarely more. The height and duration of the temperature will depend on the amount of the blood effused, but it rarely lasts more than three days. This fever may cause undue anxiety when infection is anticipated.

Fat embolism. This rare condition is usually demonstrated as a post-mortem finding. The exact mode of occurrence is not yet clear, the idea that marrow fat is somehow squeezed out into the circulation not being entirely satisfactory. The condition occurs from twelve hours to three days after the accident. At post mortem the fat globules may be demonstrated in the kidneys, brain and lungs, and the symptoms depend on which organ is most involved. Clinically there are two types, cerebral and pulmonary. The cerebral type may show delirium, muscle twitchings, or localised fits, passing into coma In the pulmonary type there are symptoms of respiratory distress, rising pulse and respiration rate, and later cyanosis. There is a normal percussion note all over the chest, but coarse rales and signs of pulmonary œdema may be present. The condition may be confused with shock, delirium tremens, cerebral complications, internal hæmorrhage, bronchopneumonia and pulmonary embolism. The latter two conditions are, as a rule, later in onset, occurring after the fifth day. The treatment of the condition is limited to general measures

Delirium. This may arise in old patients as a result of the trauma alone, and is then usually of the low restive muttering type, which calls for sedatives. More troublesome is the onset of delirium tremens, for the restlessness of the patient will destroy any retentive apparatus used to retain the fracture, other than a plaster cast, and the onset of the condition may be an indication for placing a limb in plaster which was previously being treated by skeletal traction. The onset is never sudden, and warning by hallucinations and insomnia is usually given. The tongue is heavily furred, the temperature 100° to 102°, and the pulse rapid. Delirium persists two to five days. Treatment consists of the minimal restraint necessary and adequate sedatives.

Traumatic delirium (cerebral irritation) may give rise to similar difficulties with retention. Delirium due to fever, or the onset of pneumonia, needs only to be mentioned here.

Bronchopneumonia. It must never be lost sight of that elderly patients or patients in poor general condition, or with chronic bronchitis, may develop bronchopneumonia. The immobility forced on the patient may be the main contributing factor to this, but in certain injuries, such as fracture of the ribs in the old, it may ensue

in spite of ambulatory treatment. One must be careful that a patient who is likely to develop the condition has his fracture fixed by the means allowing the greatest amount of freedom in the bed, and which, if possible, will allow the patient to be sat out. Often a complete plaster case should be substituted in many cases where in the normal individual continuous traction would be used. Care must be taken that such a plaster does not restrict respiratory movement, or is of such size as to impede movements in the bed.

The most valuable preventive is chemotherapy. This may need to be given for the injury alone, but its use must not be forgotten in the simple fracture, such as the fracture of the femoral neck in the aged, where it should be commenced immediately and continued till the patient is actively mobile in the bed, or preferably sitting out.

A further safeguard is the introduction of general exercises in bed, particularly deep-breathing exercises, which in the very feeble may be promoted by the inhalation of CO_2 for ten minutes every hour. Once symptoms appear as indicated by rise of temperature, nocturnal delirium, and moist sounds in the chest, not necessarily at the bases, every step to increase the movement of the patient and allow free respiratory movement must be taken. This often means dismantling apparatus, but it must be done as the condition is usually progressive if neglected. Where possible the patient is sat out of bed.

The crush syndrome. In civilian injuries from falling buildings and in the prolonged use of the tourniquet this syndrome may be met with. It has certain similarities to the syndrome which follows incompatible blood transfusion. It is characterised by general features due to disturbed renal function and local changes in the injured limb of a circulatory nature. Thus the limb may become swollen, pale, and tense. Arterial pulsation is reduced or absent and distal gangrene not uncommon. The blood pressure rises, the patient is liable to frequent vomiting and there is a variable mental disturbance. The output of urine is rapidly reduced, is highly acid, and in early specimens myohæmoglobin makes its appearance. Recovery is ushered in by diuresis. In fatal cases the renal failure continues and the blood urea rises. Proof that the damage to the kidney is due entirely to the deposition of hæmatin in an acid urine, with resultant tubular blocking, is lacking and the disturbed blood chemistry suggests that other factors than mere interference with filtration are damaging renal action. Treatment is directed towards slowing the release of the toxic products from the limb into the general circulation. If a limb is to be amputated the tourniquet should be left on until the last moment to avoid absorption from the limb. Cooling the limb to prevent rapid revascularisation may be

maintained at the same time as the general body warmth is raised. The immediate intravenous administration of plasma and saline with alkalis is essential in severe cases.

Injuries to Surrounding Structures

Nerves. It is convenient to discuss all the nerve injuries, including late nerve complications, together.

1. Immediate lesions may be due to concussion, stretching, contusion, crushing, or division, which may be partial or total.
2. Lesions arising during treatment.
3. Late neuritis

Immediate lesions may be complete or incomplete, and these, again, may be temporary or permanent. The more incomplete the lesion on the first examination the more likely it is to be temporary. Complete division of the nerve is uncommon, most of the lesions being due to contusion, stretching or crushing. Concussion is a very rare lesion, which is fleeting and due to the vibration set up in the tissues by the passage of a bullet in the vicinity of the nerve. It is probably a mild variety of contusion.

The indication for immediate operation on a nerve is limited to the suture of a nerve seen divided in an open wound. In all other lesions delay is advisable till the diagnosis is accurately established In most cases the nerve will recover of its own accord. The time of recovery will vary very much, depending on the injury, and in the case of severe damage to the radial nerve may be as long as six months. There is considerable disagreement as to the length of time one should wait before operating, many people preferring to explore earlier, *i.e.*, in the second or third month if recovery has not occurred rather than wait for six months In brachial plexus injuries no advantage is gained by operation. In ulnar nerve injuries, associated with fracture of the medial epicondyle, it is justifiable at the time to transplant the ulnar nerve anterior to the joint, though late ulnar neuritis is not a frequent sequel of this condition, being more common after the fractures of the lateral condyle, with subsequent valgus deformity.

Recently the disappointing results of stretching injuries to nerves have come to light. Although no loss of continuity may be visible to the naked eye there are multiple lesions scattered through the nerve at different levels In spite of their natural approximation these heal exceedingly badly Such lesions are met with most commonly in the peroneal nerve stretched by adduction at the knee joint, and less commonly in the ulnar nerve.

Nerve lesions occurring during treatment. These may be due to external factors such as the pressure of a splint or crutch.

The most common nerves involved are the peroneal as it winds around the head of the fibula from the pressure of a walking plaster and the radial nerve from the pressure of a crutch. These lesions rapidly clear up with the removal of the pressure.

The onset of paralysis in a patient free from such pressure may be confusing and cause the doctor concern as to whether manipulation has not damaged a nerve, or whether he has overlooked a lesion on the first examination. It is for this reason that it is important to make a neurological examination in any likely case when it is first seen. The onset of paralysis due to the involvement of a nerve in callus has been hotly debated, but most people have seen cases in which between the sixth and the tenth day a severe and lasting paralysis has occurred, which may take months to clear up, and the pressure of organising fibrous tissue or callus seems to be the only plausible explanation. Such cases are observed for six months, and if recovery has not occurred by this time the nerve is explored (see Fig. 281).

Late lesions. Where a fracture has resulted in an alteration of the alignment of a limb, or the production of an irregularity causing pressure on a nerve, the nerve is liable to undergo fibrosis, with the slow onset of paralysis. This may not occur till years later and is characteristically seen in the ulnar nerve following lesions of the lateral condyle which have resulted in a valgus deformity of the elbow. More commonly in elbow injuries an ulnar neuritis develops in the third or fourth weeks. This accompanies the commencement of movement in an elbow in which there is still some swelling and bruising around the joint. In these conditions the ulnar nerve has not adapted itself to alterations in its path, and the movements may stretch the nerve in the swollen tissues. This repeated stretching may lead to a paresis or temporary paralysis To avoid this complication elbow movements should be commenced gently and actively, and all forced movements avoided. Elbow movements should not be commenced too early if swelling is persistent. Should the condition occur a further period of rest will clear it up.

Vessels. Damage to vessels is an inevitable accompaniment of all fractures, but it becomes serious only when there is continuous loss of blood, or a hæmatoma under pressure. Damage to veins may produce a large hæmatoma, which is frequently subcutaneous. It is lax and does not pulsate, and the pressure of the blood being insufficient to overcome the resistance of tissues it ceases after a short time. Damage to a large artery results in the formation of a large pulsating hæmatoma, and, what is far more serious, interference with the blood supply to the rest of the limb. The pressure of displaced bone on a vessel without actual rupture may stop the circu-

lation, and this is more serious as there is then no hæmatoma to draw attention to the condition, and irreparable damage may occur before the pressure is relieved. Circulatory obstruction may also be produced by the pressure of splints, and particularly by the post-traumatic swelling of a limb in a complete plaster. Arteries are very strong and not likely to be ruptured, but they are liable to bruising which because of the autonomic supply carried in their walls may result in marked spasm of the distal vessels and partial obstruction. This is particularly seen in the brachial artery, and may be related to the onset of myositis fibrosa. Gangrene of the distal portion of the limb may follow these lesions.

Pressure on a vessel demands immediate relief by reduction of

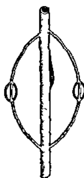


FIG. 31. Diagram of main vessels and collateral circulation showing a vascular hæmatoma without spasm. (After Cohen.)

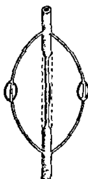


FIG. 32. Bruising of the arterial wall with local spasm.

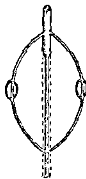


FIG. 33. Bruising of the arterial wall with distal spasm. Spasm may also follow rupture (*see* Fig 36).

the fracture, or open exploration, which may have to follow a failure of reduction to restore an adequate circulation A large tense hæmatoma will demand incision and evacuation of the clot. Not infrequently the tissues are so swollen and difficult to identify, that the release of tension is all that can be satisfactorily accomplished. With large vessels although they may have ceased to bleed their discovery and ligature become necessary, as with a rise in blood pressure further hæmorrhage may occur, and the state of the distal vessel must be ascertained as treatment directed to the relief of spasm may be necessary Where there is doubt of the efficiency of the collateral circulation arterial suture or arterial grafting may be a limb-saving measure. Temporary measures to maintain the circulation or to attempt to undo arterial spasm may be necessary while this is being arranged

ARTERIOGRAPHY. Those who have mastered the simple technique of contrast arteriography, may be saved much anxiety, as the

method enables the situation in the limb vessels to be assessed without operation. It is chiefly of value in cases in which the main vessel is intact, and an estimate of the degree of spasm and the activity of the collateral circulation is being made.

SUMMARY. The vascular changes met with may be :—

1. *Bruising of an arterial wall without spasm* (Fig. 31).

2. *Bruising of an artery with local spasm.* This may occur to the brachial artery in dislocation of the shoulder, or in gunshot wounds of the limbs. The pulse is variable, usually reduced in volume,

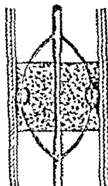


FIG 34. Local haemorrhage around a main vessel with bruising. With the limb enclosed in plaster, there is grave risk of pressure on the collaterals and of vascular occlusion.



FIG. 35. Complete rupture of a vessel retraction of inner layers and clotting

sometimes absent. It returns to normal in two to six hours. In the presence of local injury exploration is necessary, as one is not certain whether one is dealing with a complete rupture. No treatment when this is found other than local warmth provided by a few hot packs in the wound is usually necessary. If the vessel fails to relax the application of a 2·5 per cent. solution of papaverine to its outer coats may be tried.

3. *Bruising of a vessel with distal spasm.* The persistence of this spasm, and its exact mechanism are difficult to explain. The spasm may persist till the death of the limb. The acute pain is due to muscle cramp (cf. Myositis fibrosa). The association of nerve injuries may be responsible for a few cases which are painless and may be partly responsible for the persistence and failure to redistribute the blood These demand exploration and the relief of the collateral circulation from all pressure.

At operation, steps must be taken to release the distal spasm. The danger of this spasm is dependent on the length of artery involved and the involve-

ment or not of the collateral circulation. Unfortunately no certain method is known of dealing with the spasm. Local application of papaverine is of value if a short length of vessel is involved, but one cannot expose a lengthy arterial tree. Intravenous papaverine has not been found effective, but may be tried. Similar remarks apply to intravenous procaine (1 per cent.). Division of the artery has been reported as effective, but the effect on the sympathetic may be obtained by stripping its outer coat without division, a more rational procedure. In addition to peri-arterial sympathectomy, a paravertebral block may be carried out, which if it has no effect on the main vessel may affect the collateral circulation. All these procedures may prove disappointing and one may be left watching a loosely wrapped and supported limb, exposed at room temperature, for the occurrence of natural relaxation. It is the uncertain way in which this occurs that accounts for some of the difficulties in interpreting experimental observations.

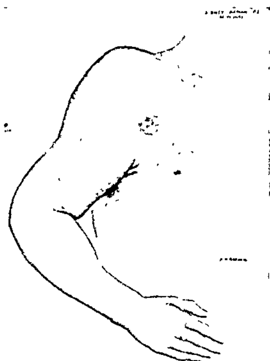


Fig 36. Anterior dislocation of the shoulder with rupture of the axillary artery, and distal vaso-spasm. Note the subcuticular bruising due to skin stretching by the humeral head, and blisters

4. *Local bruising and pressure with pressure on collaterals* This may occur in gunshot wounds, especially if put in plaster. The collateral circulation around joints is to allow for the occlusion of the main vessels in extremes of movement. It is at the joint levels that particularly large areas of a cross section of the limb are occupied by bone and pressure may readily be exerted on the

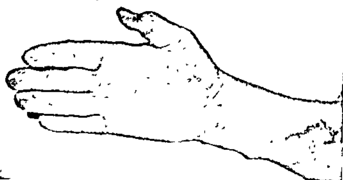


Fig. 37. Gangrene of the hand following the rupture of the axillary, and persistence of the vaso-spasm.

collaterals. The hæmatoma should be evacuated and drained if necessary, or the wound lightly packed. Care must be taken to see that there is no obstruction to the collateral circulation. A paravertebral block may be tried. The limb should be kept at room temperature, though the patient's body may be warmed. Failure to recover may be due to inadequate collateral circulation, *e.g.*, in damage to the popliteal vessels, unsuspected distal spasm, or an arterial clot in the distal circulation.

5. *Complete rupture of a vessel.* If the vessel ends can retract there is often little bleeding. Danger arises from thrombosis in the distal end or pressure on the collaterals, inadequate collaterals or distal spasm. Partial division of a vessel which prevents the normal retraction and rolling up of the coats is productive of the most severe hæmorrhage. Discovery of the vessel in the bruised tissues may be difficult, and if exploration is likely to disturb the collateral circulation may be unwise.

Where there is doubt of the efficacy of the collateral circulation, as in divisions of the popliteal, the common femoral, or the subclavian artery, the question of arterial suture must be considered. Loss of tissue may be replaced by an arterial graft. If no stored graft is available, the superficial femoral may be used. Some special experience is required, though the technique is more painstaking than difficult.

Under these circumstances, or where distal spasm has occurred the transfusion of the distal stump of the vessel with oxygenated and warmed blood is of value in prolonging the chances of the limb to survive. As vasodilators 1 per cent. procaine, or 2·5 per cent. papaverine may be added to the transfusion.

AFTER-TREATMENT. Never use traction where there is any question of the impairment of the blood supply. Plaster also should be avoided, but it may be necessary to use padded plasters or plaster gutter splints. Always elevate the limb ; a slung skeleton splint is usually most convenient. Keep the limb cool rather than overheat it Remember that the circulation in the deep tissues is what counts, and the skin circulation is an unreliable guide to this.

Joints. Joints may be injured in association with fractures in the following ways :

1. The fracture may run into the joint, or be entirely intra-articular

2. The fracture may result in the normal alignment of the limb being altered, with subsequent strain on the joint.

3. A dislocation may be associated with a fracture.

4. A mal-united fracture in one leg may throw so much strain on the other that a *traumatic arthritis* may develop on the uninjured side from repeated minor strains.

It has been emphasised before, and will be emphasised again,

that the serious feature of a fracture is the damage to soft parts and not the fracture itself. It is still more serious when the fracture involves a joint *and to altered alignment is added an irregularity of* the joint surface. An effusion of blood into the joint is inevitable. In the knee it is liable to assume large proportions, and aspiration is advisable. This is necessary as a preliminary to any manipulations, and to the accurate fitting of a plaster, while the removal of the blood probably decreases the adhesions which may form. Much the most important features of the injury are the later sequelæ, limitation of movement and traumatic arthritis.

In open wounds the escape of a few drops of synovial fluid into the wound, which can readily be appreciated by rubbing the fingers dipped in the exudate, may help to decide whether a joint is involved. A somewhat similar slippery sensation may be imparted by marrow fat, so that in the presence of a fracture below the wound the test may *be unreliable. A more valuable test, if a decision has to be made, is to* inject penicillin into the joint, and see if it escapes into the wound.

It must not be forgotten that cartilage injury alone will show no irregularity or shadow in the X-ray. Only if a flake of bone is torn off with the cartilage (as in arthritis dissicans) will the damage be seen in the radiograph. Thus in fracture of the head of the radius, damage to the cartilage of the capitellum (as shown by operation) frequently occurs, and is overlooked and unsuspected till recovery fails to occur in the usual time.

Dislocation associated with a fracture is an added source of trouble The fracture may make adequate reduction of the dislocation difficult as in fracture dislocation of the shoulder, or *vice versa*, as in fracture dislocations of the spine.

Viscera. The viscera liable to damage are discussed in the complications of special fractures The principal dangers are due to infection or to hæmorrhage

Skin The importance of skin cover of a fracture or indeed of any soft tissue wound will be discussed in the chapter on compound fractures. It is necessary to remind students however of the risk of skin necrosis associated with a tense hæmatoma, or in certain cases of dislocation and fracture in which skin may be stretched over displaced bone, *e.g*, complete dislocation of the talus. In the case of a hæmatoma, incision followed by drainage for forty-eight hours is necessary. Early reduction of the deformity is essential where the skin is stretched if necrosis is to be avoided.

FURTHER READING

Shock

Huston. " Shock : its Prevention and Treatment." S. Clin. North America, April, 1935, 287. (Contains a summary of the American work.)

Bond and Wright. "Treatment of Hæmorrhage and Traumatic Shock by the intravenous use of Lyophile Serum," *Ann. Surg.*, 1938, **107**, 500.
Frazier. "The Modern Treatment of Surgical Shock," *J.A.M.A.*, 1935, **105**, 1731.
Mahoney, E. B. "A Study of Experimental and Clinical Shock, with Special Reference to its treatment by the intravenous injection of preserved plasma," *Ann. Surg.*, 1938, **108**, 178.
Blalock. "Acute Circulatory Failure as Exemplified by Shock and Hæmorrhage," *Surg. Gynec. and Obst.*, 1934, **58**, 551.
Levinson, Nowelt and Nechelles. "Human Serum as a Blood Substitute in the Treatment of Hæmorrhage and Shock," *J.A.M.A.*, 1940, **114**, 455.
Meakins, J. C. "Shock, its Cause and Treatment," *Canad. Med. Ass. Jour.*, 1940, **93**, 201.
Moon, V. H. "Early Recognition of Shock. Differentiation from Hæmorrhage," *Ann. Surg.*, 1939, **110**, 260.
Dunphy, J. E. "Shock. A Consideration of its Nature and Treatment," *Brit. J. Surg.*, 1944, **32**, 66.

Fat Embolism

Rowlands and Wakeley. "Fat Embolism," *Lancet*, 1941, *i.*, 502.
Scott and Kemp. "Pulmonary Fat Embolism," *Lancet*, 1942, *i.*, 228.
Newman, P. H. "The Clinical Diagnosis of Fat Embolism," *J. Bone and Joint Surg.*, 1948, **30B**, 290.
"Fat Embolism," *The Lancet*, 1952, *i.*, 196.
Glas, W. W. *et al.* "Fat Embolism," *Am. J. Surg.*, 1953, 363.
Aldred, A. J. "Fat Embolism," *Brit. J. Surg.*, 1953, **41**, 82.

Nerve Injuries

Platt, H. "Peripheral Nerve Complications of Fractures and Dislocations of the Elbow." Robert Jones Birthday Volume. London, 1928, p. 195.
Platt and Bristow. "Remote Results in Operations for Injuries of the Peripheral Nerves," *Brit. J. Surg.*, 1923, **11**, 535.
Platt, H. "Traumatic Neuritis of the Ulnar Nerve in the Post-condylar Groove," *Brit. J. Surg.*, 1925, **13**, 409.
Platt, H. "Peripheral Nerve Complications of Certain Fractures," *J. Bone and Joint Surg.*, 1928, **10**, 403.
Davidson and Horowitz. "Late or Tardy Ulnar Nerve Paralysis," *J. Bone and Joint Surg.*, 1935, **17**, 844.
Parkes, A. R. "Traumatic Ischæmia of Peripheral Nerves," *Brit. J. Surg.*, 1944, **32**, 403.
Seddon, H. J. "War Injuries of Peripheral Nerves," *Brit. J. Surg.*, War Surgery Supplement, No. 2, 325.

Injuries to Vessels

Dodd, H. "Gangrene following Fractures (excluding Gas Gangrene), [illegible] of the types of injury, the vessel
Cohi [illegible]" *Lancet*, 1944, *i.*, 1.
M.R [illegible] ...al Injuries," War Memoranda, No. 13, 1944.
Kinmouth, J. B. "The Physiology and Relief of Traumatic Arterial Spasm," *Brit. M. J.*, 1952, 1, 59
Griffiths, D. L. "Acute Circulatory Failure in the Injured Limb," *J. Bone and Joint Surg.*, 1948, **30B**, 280.
Bowden, R., and Guttman, E. "Fate of Voluntary Muscle after Vascular Injury," *J Bone and Joint Surg.*, 1949, **31B**, 356.

CHAPTER VI

THE LATE COMPLICATIONS OF FRACTURES

Late Complications

1. Infection. (See compound fractures, Chapter IX.)
2. Non-union. (See Chapter X.)
3. Mal-union. (See Chapter X.)
4. Late neuritis. (See Chapter V.)
5. Myositis ossificans and ossifying hæmatoma.
6. Myositis fibrosa. (Volkmann's ischæmic contracture.)
7. Acute traumatic bony atrophy.
8. Joint stiffness and adhesions.
9. Traumatic arthritis.
10. Avascular necrosis. (See Chapter II.)
11. Œdema and vascular disturbances.
12. Nephrolithiasis.

Myositis Ossificans and Ossifying Hæmatoma

It is customary to apply the term myositis ossificans to any flake of bone found in the muscles, but distinct from, the injured bone. This is an equivocal use of the term, which was once limited to a single clinical entity in which some inflammatory features were present It now covers several conditions.

1. New bone formed in the vicinity of displaced fragments of bone or cartilage.

2. Extensive new bone formation in tissues in the vicinity of a fracture which were involved in the fracture hæmatoma.

3. Patchy new bone formation in muscles at some distance from the fracture and not directly involved in the fracture hæmatoma.

4 True myositis ossificans, the formation of new bone accompanied by pain and other features of inflammation, and now less commonly seen than under old methods of treatment.

The formation of callus commences first at the junction of the stripped periosteum and the shaft, and slowly extends into the hæmatoma, gradually encroaching on the fracture site till it joins the callus extending from the opposite side. At the same time there is a tendency for the hæmatoma to diminish in size. If the hæmatoma is very large, or the periosteum is torn and displaced into the muscles around the bone, the ossifying process may extend into the surrounding tissues, and this is particularly marked in comminuted fractures. We have stated that ossification is not a specific property of the cambium cells of the periosteum, but that any

fibroblast may under certain conditions become an osteoblast and lay down collagen fibrils, among which calcium and phosphorus are deposited to form new bone. The cambium cells of the periosteum merely serve as a store of readily available cells which rapidly produce fibroblasts. In the first two conditions mentioned the muscle is involved because it forms part of the fracture hæmatoma. This may be serious, as, for example, in the thigh, where the quadriceps may develop extensive adhesions to the femur, limiting knee



FIG 38 Ossifying hæmatoma in the brachialis anticus, following fracture of the ulna with anterior dislocation of the head of the radius. (Sequel to the fracture shown in Fig 387.) The outlines of the new bone are now sharp and well-defined due to the organisation of a fine layer of compact bone on the periphery, indicating that all activity has ceased and light, active exercises can be indulged in without fear of extension of the mass.

movements. *Such hæmatomas show a rounded and definite outline* and usually some connection with the callus at the fracture site. Occasionally only small areas of the hæmatoma undergo calcification due perhaps to the presence of a bone fragment, or the displacement of periosteum, and show no connection in the radiograph with the shadow of the callus. Such an ossifying hæmatoma should be left, and *will gradually decrease, particularly in the young*

The conditions resemble those of *heterotopic bone formation* elsewhere, such as "rider's bone" in the adductor longus, or bone formation in fibrotic scars, but the formation is in this case related to the repair process which is going on in the vicinity. According to

Leriche and Policard, whose theory is related to the facts, but is not the whole truth, under these circumstances we have the essential conditions present in which ossification occurs.

1. We have an active blood supply in the organising hæmatoma.
2. An ossifiable mediun [illegible]
3. Excessive calcium fr [illegible]

Any damage to a mus [illegible] a slight fibrosis may become involved in this cycle. The stimulus changing the direction of the fibroblast from fibrous tissue formation to bone is considered in this hypothesis to be the local calcium excess, but though this is part of the truth it is not all of it. Observation of many cases and the study of the repair of bone makes one certain that any further tissue injury in the vicinity of the repair process will result in the rapid extension of the ossification, and many cases in which the condition develops give a history of early forced movements. The condition is particularly common in the elbow region, and is to be avoided by giving adequate rest to the joint before movements are attempted, usually a period of three to four weeks, and then to commence gentle active movements. In all cases forced or violent active or passive movements are to be avoided. The effect of such movement can be seen readily if the angle of the elbow in extension and flexion is measured weekly. If, following an elbow injury such as a supracondylar fracture, there is a progressive decrease in the range of movement, it is almost certain that inquiry will reveal forced movements, such as the carrying of a school satchel or the well-meant effort of a parent to get the arm straight.

Treatment. This falls into two stages. In recent cases, in which the outline of the callus in the radiograph is soft, time will usually result in absorption of the deposit altogether or in part. The degree of fixation necessary to encourage this is debated. If there are any acute symptoms such as swelling or pain, the joint must be completely rested. If the joint is painless the advantage of absolute fixation in plaster is doubtful, and equally satisfactory results are achieved by merely avoiding heavy work and forced movements, while leaving the arm free for lesser activities.

If the lesion is old and the bone well organised with a sharp, dense outline (Fig. 38), operative removal is required if it is obstructing movement. In many cases there will be little disability in spite of its presence, and there is then no need to interfere. Care must be taken during the operation to do as little damage to soft tissues as possible and avoid the formation of a fresh hæmatoma.

Myositis ossificans. The condition to which this was first applied is most commonly seen in the elbow region. It takes the form of a fairly acute inflammatory reaction with heat, pain, redness,

swelling and tenderness in the vicinity of the fracture, which is obviously a much more active lesion than the repair processes on which it supervenes. It occurs at any time after the first three days up till the end of the third week. It is rapidly followed by calcification and ossification in the involved tissues. The exact ætiology of the condition is not clear, it may be sub-acute inflammatory in nature, or more probably chemico-pathological, following vasomotor changes. It produces larger masses of new bone than is usually found with the more passive processes previously described, and organisation is slower. Characteristically the new bone formed indicates the outline and direction of the bundles of muscle fibres of which the muscle is composed (Fig. 39). The treatment, which consists of complete rest in the acute stage, must be prolonged. Removal of organised fragments is very likely to be followed by a recurrence, and the extent of the condition usually renders this impossible. Slow recovery over a long period may occur, but some permanent disability is the rule.



FIG. 39 Myositis ossificans in the brachialis. This specimen of true myositis ossificans shows extensive involvement of the muscle with calcification occurring along the lines of the smaller intramuscular septa

OSSIFICATION IN LIGAMENTS. A similar process of organisation of a hæmatoma in a ligament, assisted perhaps by the presence of minute flakes of avulsed bone frequently results in the formation of new bone in the vicinity of joints. In the absence of any history of injury these may be mistaken for a fresh avulsion fracture. They may be distinguished by their irregular outline, patchy density, multiplicity, the absence of signs of acute injury, and the unbroken surface to which the ligament is attached.

Myositis Fibrosa (Volkmann's Ischæmic Contracture)

The decrease in the incidence of this condition is due to the idespread recognition of the risks of certain forms of treatment

Leriche and Policard, whose theory is related to the facts, but is not the whole truth, under these circumstances we have the essential conditions present in which ossification occurs.

1 We have an active blood supply in the organising hæmatoma.
2 An ossifiable medium, that of the growing fibroblasts.
3. Excessive calcium from absorption in the vicinity.

Any damage to a muscle in the vicinity resulting in a slight fibrosis may become involved in this cycle. The stimulus changing the direction of the fibroblast from fibrous tissue formation to bone is considered in this hypothesis to be the local calcium excess, but though this is part of the truth it is not all of it. Observation of many cases and the study of the repair of bone makes one certain that any further tissue injury in the vicinity of the repair process will result in the rapid extension of the ossification, and many cases in which the condition develops give a history of early forced movements. The condition is particularly common in the elbow region, *and is to be avoided by giving adequate rest to the joint before* movements are attempted, usually a period of three to four weeks, and then to commence gentle active movements In all cases forced or violent active or passive movements are to be avoided. The effect of such movement can be seen readily if the angle of the elbow in extension and flexion is measured weekly. If, following an elbow injury such as a supracondylar fracture, there is a progressive decrease in the range of movement, it is almost certain that inquiry will reveal forced movements, such as the carrying of a school satchel or the well-meant effort of a parent to get the arm straight.

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MYOSITIS OSSIFICANS The condition to which this was first applied is most commonly seen in the elbow region. It takes the form of a fairly acute inflammatory reaction with heat, pain, redness,

tion the contracture which characterises myositis fibrosa does not occur. We must therefore seek for the special factors which produce this contraction, and it has been suggested that they are vascular or neurological, or a combination of both. The acute symptoms subside and at the end of three days early contraction can be noted. This becomes more and more marked so that the fingers are first flexed, then the wrist, and in severe cases even the elbow. In the fully developed state the lesion is easily diagnosed. The wrist is flexed and the fingers extended at the metacarpo-phalangeal joints, due to the action of the extensor digitorum communis, and flexed at the inter-phalangeal joints due to the inability of the lumbricals and interossei to oppose the contraction. The forearm in severe cases is flexed and pronated. The fingers can be extended if the wrist is fully flexed, but on extending it the fingers forcibly flex again. The condition reaches a maximum ten to twenty weeks after the injury. Fully developed cases are not overlooked, but the mild cases may be very readily missed. They come up some time after the injury, usually to a different doctor, and with no story suggestive of myositis. They are confused with nerve lesions, contracture of the palmar fascia, tenosynovitis, and contractions of the fingers. Careful history taking and examination should suggest the cause.

PATHOLOGY. The pathological peculiarity which characterises myositis fibrosa is the contraction of the fibrous tissue which forms in the muscles affected. It is highly probable that this is due to some unusual trophic disturbance of the muscle as similar contractions may be seen in other vasomotor disturbances. It is theoretically possible that this change may be produced by either venous obstruction or arterial occlusion, and it would seem that this is the only possible explanation of the divergent views expressed as to its ætiology.

Brooks' theory. This theory, of old standing, states that the obstruction is venous in origin, and was based on experimental work. It was found that the blocking of the artery to a muscle alone produced no contracture. That the blocking of artery and vein were equally without effect, but that contraction followed the blocking of the vein alone. Further support was lent to the idea by the fact that the venous return from the forearm muscles which are most commonly affected occurs through one large vein As this vein crossed the anti-cubital fossa it was susceptible to pressure, and as a rise in pressure in this space seemed to be an inevitable accompaniment of the condition, here was a convenient explanation.

In observed cases the condition has arisen following tight bandaging of the arm to the chest for fractures of the clavicle, also

in fractures in the elbow region. This care must not be relaxed by the profession because the condition may also be found apart from all treatment. The responsibility for the condition is so frequently laid at the door of treatment that a surgeon who neglects the warning signs and allows the condition to develop will lay himself open to an action for malpraxis. Such a risk makes it important that the various factors related to the condition be fully discussed.

The deformity is due to shortening of the flexor-pronator group of forearm muscles secondary to a replacement fibrosis of the muscles with subsequent contraction. It is invariably associated with circulatory changes of the limb in both the onset stage and the late stage. The association of the condition with vascular and nervous features has led to a thorough examination of both these factors as the possible causative agents—the nervous damage appears to be an associated phenomenon due to either nerve damage at the time of the injury, or secondary to ischæmia of the limb. Of the vascular possibilities both the venous and the arterial sides have been held responsible, but the ætiology of the condition is not yet clear.

Clinically the condition may be divided into three stages :

1. Threatening stage.
2. Developed acute inflammatory stage.
3. Stage of fibrosis and contracture.

First stage. In this stage, which is not uncommonly seen, the patient will complain of severe pain in the limb, the fingers will be swollen and engorged and the movements limited. There may be some interference with the radial pulse. With correct treatment (to be discussed later) this will pass off and the condition may completely recover. Partial recovery may occur with a slight degree of contraction later in one or two fingers, indicating that the second stage has developed in a few muscle bellies.

Second stage The symptoms and signs mentioned above are present in an aggravated form. In the actual muscles involved changes of an acute inflammatory nature occur. The muscles are tense, swollen and œdematous, of a bluish colour, due to congestion combined with multiple capillary ruptures and hæmorrhage into the muscles. This is followed by an invasion of lymphocytes and phagocytes among the muscle fibres, which soon lose their characteristics and degenerate At this stage the fascia of the forearm is very tense and frequently the skin is almost equally tense, due to the gross swelling. Finger movements are impossible and, if passively made, excessively painful The fingers are held flexed. Symptoms of nerve pressure or paralysis may be apparent.

Third stage. This is the stage which characterises the condition. In the fibrosis which follows arterial obstructions and nerve degenera-

within eight to forty-eight hours of the fracture, but in a few cases it has apparently occurred later, but such cases usually give a history of some manipulation or change of treatment some days after the injury, and the lesion develops within eight to twenty-four hours after this, so that the primary cause in these cases was the second manipulation. Such reported cases are probably not



FIG. 40. Acute bony atrophy (Sudeck's) of the hand. Note the concentration of the maximum rarefaction around the joints.

due to the contracture being overlooked, as there was no pain noted in the first instance, and this is an almost inseparable accompaniment of the inflammatory stage. As contraction sets in after forty-eight hours, and such reported cases have occurred after intervals of several days, contraction would be certain to be established, and could hardly be overlooked.

The condition is not uncommonly seen in the leg, either as the result of too tight plastering, or, more commonly, following lesions

in unsplinted fractures in the elbow region. Cases of prolonged use of the tourniquet, various crushing injuries of the forearm, rupture of the brachial artery, and, most frequently, splinted fractures of the elbow region, have all given rise to cases of contracture. Assuming Brooks' theory to be correct, pressure in the ante-cubital fossa may arise from the rupture of a small artery into the space, the pressure of displaced fragments of bone, or the anteriorly displaced end of the humerus, or from traumatic swelling and œdema.

Brooks' theory has however not explained the loss of radial pulse often noticed, or the occurrence of the condition, apart from the ante-cubical swellings and in other regions.

Arterial theory. Contusion or pressure on the brachial artery by a fragment of bone has been seen at operation to cause intense spasm of the vessel, which is continued into the distal branches. This spasm is sufficient to reduce the blood flow through them to almost nil, and is persistent. The long-continued partial or complete obstruction to the circulation in the limb thus accounts for the loss of the radial pulse, and the peripheral vascular features which characterise the condition. The subsequent microscopical changes fit in satisfactorily with an avascular necrosis of the muscle cells, followed by a peculiarly active fibroblastic replacement. Clinically it has been shown that the vasospasm can only be relaxed with great difficulty, and some times not at all (see p. 55).

Absence of a radial pulse is thus a justification for exploration of the brachial artery, with which may be combined the release of tension in the ante-cubital fossa and the flexor group by a long fascial incision.

Clinical. In watching suspected cases it must be remembered that certain signs may be absent For example, the condition may develop without loss of the radial pulse, which cannot alone be used as a criterion of safety. Loss of the radial pulse from the beginning suggests pressure on the brachial artery from the fracture, and should the reduction of the fracture fail to restore this, it is an indication for operative exploration, especially if accompanied by other signs of circulatory failure in the hand. Myositis fibrosa may also develop in an arm without complaint of pain, though this is usually severe and bitterly complained of Swelling, loss of function of the flexor muscles, and circulatory disturbances such as pallor, cyanosis, and coldness are found in all cases, and these are sufficient to justify active interference It must be remembered that nerve symptoms are present in 50 per cent. of cases, the median and ulna being the more commonly affected nerves. Involvement of these nerves may account for a few cases in which there is no complaint of pain. The time of onset of the condition is most commonly

the veins and then on the arteries, with, in severe cases, the total obstruction of the circulation of the limb. Before such a condition is arrived at, however, the signs of threatening myositis fibrosa will have occurred.

In the threatening stage. All apparatus must be removed at once, and the situation considered. If the fracture has not been reduced this is done at once and the progress observed afterward. If possible the arm is placed in Zeno's position (Fig. 271), and held there with a plaster slab and a sling, or a wire through the olecranon. If the fracture has been reduced the limb is similarly suspended. It is then carefully watched and if within one and a half hours no change is noted in the condition of the circulation the fascia of the forearm is incised and the lower third of the brachial artery explored. The incision, 6 inches long, lies over the muscle group and the artery. Spurting vessels are tied and the wound drained and lightly sutured. The arm is then slung up in Zeno's position. The fracture is not exposed during this procedure if possible.

The developed condition. The treatment of this is not the province of this book, but in the earlier cases care must be taken to prevent contraction occurring by adequate splintage. This is best done by incorporating a frame of Cramer wire in plaster so that it overhangs the dorsum of the hand. From this the fingers are suspended by strings and a small volar pad. The spring of the Cramer wire exerts a continued pull on the fingers and this can be tightened daily by retying the suspensory tapes. Early contraction can be counteracted by this method and old contraction to some degree corrected. As the damaged muscles do not regenerate there is no possibility of the return of function, but the fingers are much more useful if they are not excessively flexed (Fig. 41).

Ultimate outlook. In early cases which are rapidly relieved by the removal of splints the outlook is good. In slight cases the disability is not very crippling. In severe cases, especially with nerve complications, the outlook is poor, and in the established case there is little hope of improvement, some diminution in flexion of the fingers is all that operative interference other than muscle transplants produces.

Acute Traumatic Bony Atrophy

Following the immobilisation of any limb there is a certain degree of decalcification of the bone as shown by the X-ray (disuse atrophy). In certain cases in which the pathology is not at all clear this decalcification progresses at an abnormal rate. It may further show the abnormality of being confined to a comparatively limited area, such as the hand. It may follow a very minor lesion and be

of the upper end of the tibia, in which the posterior tibial vessels are injured. They are peculiarly susceptible to pressure where they lie under the fibrous arch of the popliteus, and pierce the interosseus membrane. The changes are similar to those in the hand, persistent vascular disturbance being even more troublesome in the foot.

Treatment. *Prophylactic or precautionary.* As the condition is most commonly associated with lesions in the elbow region it is important to observe such cases for twenty-four hours after treatment. As pressure on either vein or artery will persist if the fracture is unreduced, early reduction is important in all cases. This can



Fig. 41. [illegible]

stiffness in flexion.

usually be done by manipulation, which should be the minimal necessary, to avoid further damage and hæmorrhage. Retention should also be the minimal necessary. A plaster slab bound on with a gauze bandage is sufficient, the elbow being maintained at right angles, as acute flexion is liable to produce pressure. Morphia should not be given as it may mask the pain, which is an important premonitory symptom, and the pulse and circulation should be regularly observed. The patient is better in bed to avoid the increased swelling due to a dependent arm.

Traumatic swelling and œdema will not as a rule cause trouble if there is room for the swelling to occur, but if the arm is tightly splinted, or acutely flexed, the swelling may cause pressure, first on

treatment, particularly so if there is any previous tendency to arthritis.

5. Sepsis in the region of the joint.
6. Burying foreign bodies near the joint.
7. Ossifying hæmatomas and myositis ossificans.
8. Flare up in a joint disease due to injury or immobilisation.
9. Excessive skeletal traction through a joint.

Most of the conditions outlined above have been discussed elsewhere. In a general discussion it is important to emphasise that joints should only be fixed for a reasonable period. This period varies with each fracture and each joint. Generally speaking fractures near joints should be given time to become firm before the joint is moved, but movements of all unfixed joints, and of muscles running over fixed joints should be *encouraged*. *In the upper limb* gentle active movements can be begun as soon as the callus is firm. In the lower limb the callus will yield with the body weight and it must be supported with a walking plaster or calliper, for the exercise of walking not only improves muscle tone and development, but it is reflexly concerned in the nourishment of the joint, which after prolonged immobilisation is often surprisingly mobile if the limb has been actively used.

The joints of the young can be immobilised for months without fear. The joints of the old must be immobilised for the shortest possible time. Joints already the seat of osteoarthritis stiffen very rapidly. In the old methods of treatment which permit early mobilisation have to be chosen, and position often sacrificed to function.

Peri-arthritis of the shoulder. This disabling condition follows injuries to the shoulder, particularly in older patients. The short rotator cuff of the shoulder is liable to degenerative changes with age. This may produce stiffness without a history of injury, but a trivial injury is often the precipitating factor. Changes in the rotator cuff affect the floor of the subacromial bursa and adhesions here add their quota to the stiffness. Partial ruptures of the short rotator cuff add difficulties in diagnosis and are responsible in some cases for the stiffness (see p. 324). Characteristically all movements of the shoulder are limited and painful. The patient cannot put the hand behind the head, or behind the back. Active abduction can be commenced and often carried up to 90 degrees. After this passive abduction may produce a further few degrees but resistance is then met with. The joint is painful, and the patient cannot sleep on that shoulder. The radiograph is usually normal A characteristic accident causing it is a Colles' fracture in an elderly patient in which

out of all proportion to it. Sudeck, who first drew attention to the condition, regarded it as a neurotropic manifestation. In support of this is the fact that it is frequently associated with skin changes and peripheral circulatory disturbances and impaired sensation. The condition most commonly affects the hands and feet. Two conditions are recognised as predisposing to its development, a period of partial vascular obstruction under a tight plaster, and multiple attempts at reduction in elderly patients. Both should therefore be avoided. In the hands there will be complaint of disproportionate pain and stiffness. The skin will become shiny and red and susceptible to cold, when it turns a cyanotic blue. An X-ray distinguishes the condition from the pure neurotropic manifestations. The bones will be found to have a mottled appearance, with marked decalcification in the regions of the joints. There will be a general decalcification of all portions of the bone in comparison with the normal side. Variable degrees of soft tissue contraction accompany the condition, particularly affecting the capsular ligaments of the inter-phalangeal joints, and in certain cases this is marked and resistant. The severe case is very rare, but the mild case in which the bony atrophy progresses past the normal is not uncommon. In this latter group the soft tissue contraction is small, possibly only preventing full extension of the fingers, and with use the normal calcification is restored. In the serious cases there is no more disappointing lesion to treat. Recently paravertebral sympathetic block has been suggested for the early case, but as the lesion is accompanied by vasodilatation it is not obvious how this would act. In the absence of any other method of attack, it is however worth trying. In the established case vitamin concentrates and calcium in the diet are given, together with local treatment in the form of radiant heat, contrast baths, massage, exercises, and electrical stimulation of the muscles. In the less severe cases movements will return to some extent, but in the majority of cases the hand is crippled for life.

Joint Stiffness and Adhesions

This is one of the most disabling conditions following fracture, and one which should be more frequently avoided than is the case. The borderline between these cases and traumatic arthritis is not sharp. The condition may arise from :

1. Actual fracture into the joint. (Traumatic arthritis later.)
2. Bruising of the joint with no X-ray evidence of fracture. Possibly osteochondritis dissicans later.
3. Bruising and damage to peri-articular structures.
4. Degeneration and fibrosis around a joint immobilised in

the fracture due to alteration in the lines of force passing through the joint from mal-union of the fracture. Such arthritis may occur in the opposite lower limb to that injured from the excessive use of the uninjured limb in an attempt to protect the injured one. Such cases are really an osteo-arthritis from excessive strain.

The condition is usually a low grade chronic inflammatory one without of course any bacterial basis, the pathology resembling that of monarticular osteo-arthritis. It is accompanied by pain and swelling, and progressive deterioration of the joint with loss of cartilage, flaking and eburnation of bone, and later the formation of osteophytes. Any of the factors mentioned in the ætiology of adhesions may be an associated or primary cause of the condition. It is commonly found in the hip after fractures of the neck of the femur, and in the elbow and knee after fractures into the joint.



Fig. 42. Early traumatic arthritis of the elbow, following fracture of the head of the radius, showing lipping of the sigmoid notch, small loose body in the joint, and rarefaction of the capitellum.

The condition is in general relieved by rest and aggravated by exercise. Patients with arthritic lesions elsewhere are particularly prone to develop the condition, and it may be difficult to decide if it is the original arthritis or the accident which is more to blame for the condition. These cases are unsuitable for any but palliative physiotherapeutic treatment or if severe for some radical surgical interference.

The aim of treatment is to avoid the development of the condition, which once developed shows a strong tendency to progress, even if the original cause is removed. Thus if a displaced head of the radius is left *in situ*, and gives rise to a traumatic arthritis, its late removal may result in very little improvement in the condition. Early removal to avoid the complication is indicated. No one was more insistent on the need for perfect reduction to avoid this compli-

the arm has been kept in a sling during treatment, and the shoulder unexercised. On removal of the sling the disability is apparent. It is due to immobilisation combined with bruising of the shoulder.

Treatment consists of short-wave diathermy to the shoulder, massage, and active exercises. Progress is slow, and some permanent limitation of shoulder movement the usual result. Manipulation must be judicious if employed, as forced movements may set the cycle of trouble in action again. Multiple manipulations gaining a little at a time are best. Pain, though slow to go, eventually disappears. Elderly people often accommodate themselves to the limited movements easily, and are best left to do so.

Manipulation. In all stiff joints this must be considered. Contra-indications to manipulation are the presence of bony blocks such as from ossifying hæmatomas, myositis ossificans, joint deformities causing blockage, and recent cases with effusion into the joint or surrounding tissues. The ideal joint for manipulation is one in which all active repair processes have subsided, and there is limitation of movement in one or two directions only, indicating fibrosis in the joint blocking these movements. Where all the movements of the joint are limited there is little chance of improving the condition by manipulation, as the fibrosis is too heavy, and breaking it down results in a further crop of adhesions still more solid than the first. Similarly, in the presence of chronic arthritis of any severity, manipulation will not restore movement to any extent, though it may relieve pain and stiffness.

The most dangerous causes of joint stiffness however remain; failure to exercise a joint early, failure to exercise all immobilised joints in the aged, and the use of skeletal traction. This last is a potent cause of trouble, not only because of sepsis along the pin track, but because the forcible distraction of a joint in the reduction of a fracture inevitably damages ligaments, which stiffen up in the subsequent period of immobilisation. The use of continuous traction for too long or with too great a weight is also dangerous. In avoiding these pitfalls open operative reduction has a great advantage over other methods

Traumatic Arthritis

This general name is applied to several conditions

1. The arthritis, which immediately follows fracture into the joint with displacement.

2. The arthritis which develops later in a joint due to injury to the joint surface, or alteration in the normal relations of the joint or the line of the limb.

3. Arthritis developing in joints which are some distance from

1. Deep thrombosis of the tibial veins during treatment.

2. Extensive subcutaneous scarring with diminished venous return.

3. Chronic lymphangitis from an attack of streptococcal lymphangitis. ("Wound erysipelas.")

4. Vasomotor disturbances of an unexplained type, sometimes associated with nerve lesions, but occurring in their absence and often following comparatively trivial injuries, *e.g.*, sprains.

These forms may be distinguished from the physiological types by their persistence, the failure of the œdema to subside with rest, or elevation of the part, its localised site in certain cases, the firm resistant quality of the œdema, and the occasional obvious ætiology. *Deep thrombosis* of the tibial veins may be demonstrated by a venogram, and is followed by the development of varicose veins. The treatment of these is unwise while the deeper veins remain blocked. Where lymphatics are blocked and there is extensive scarring, full thickness grafts of skin and subcutaneous tissues (tubed pedicle grafts of flaps), may restore normal lymphatic and venous channels. Vasomotor disturbances being of uncertain pathology are naturally the most unsatisfactory to treat. The localised forms may be treated by regular weekly infiltrations with novocaine, and physiotherapeutic measures to improve vascular tone, contrast baths, short-wave therapy. The more generalised forms, affecting the whole limb, or the distal portion of it, may respond to sympathetic block, or to sympathectomy. This group remains both the most unsatisfactory and the most interesting on account of their indeterminate nature.

Nephrolithiasis

The development of renal stone in cases recumbent for a long period has been observed for many years. It is due to a combination of defective renal drainage from the position, and the decalcification of the skeleton due to disuse. This decalcification is greatly increased by sepsis in the neighbourhood of the bone, or in the bone itself, and this is an important factor in the ætiology. In 90 per cent. of cases the stones are of calcium phosphate, and the chief factors in their formation seem to be physico-chemical rather than infective, as renal infection is uncommon in the early stages of their development. The calculus is discovered by X-ray, usually accidentally, in a film of the spine, or from an attack of renal colic when the patient moves in the bed

To avoid this development patients who are to be recumbent for a long period should be given fluids freely, and turned regularly in bed to get complete drainage of the renal pelvis, the urinary reaction

cation than Arbuthnot Lane, and time has proved his contention. Post-traumatic strain from malunion is most important in the lower limb, where the disturbance of the line of transmission of the body-weight throws unequal strains on either side of a joint. This may apply to the leg involved, or to the opposite leg, which may be subjected to strain to balance the affected limb. Where a joint is involved in damage the subsequent traumatic arthritis develops as a result of frictional strain as well of intra-articular strains. The importance of perfect reduction of fractures in the vicinity of all joints, and of any fracture of the lower limb, is thus a strong argument for the use of open operative methods of reduction in fractures.

Treatment. In early cases this may be difficult to decide. If the deformity is gross, operative restoration of the normal may be attempted. In the young this is obviously desirable, but in the old, especially if the deformity has been established any length of time, a certain amount of adaptation has occurred and a fresh alignment merely substitutes a fresh series of strains for the old. Often palliative measures are all that can be prescribed, such as firm bandaging or the wearing of a moulded support. A course of physiotherapy may give symptomatic relief. The possibility of temporary relief and improvement by manipulation must be kept in mind.

In well-established cases the treatment is similar to that of osteoarthritis. Palliative measures like massage and other forms of physiotherapy are used, together with a support to the joint such as a calliper or knee cage. If this does not relieve the patient recourse must be had to arthroplasty, osteotomy to alter lines of strain or arthrodesis.

Œdema and Vascular Disturbances

Following the removal of any plaster which has been worn for a week or more there is a reactionary œdema, particularly in the lower limb, which varies with the age of the patient, the type of plaster and the lesion. Such an œdema limits the movement and use of the limb leading to stiffness of joints, and requires to be controlled. This is best done by applying some form of elastic stocking to the limb immediately after removal of the plaster and before the swelling has time to occur. It will be necessary to keep this stocking on for approximately half the length of time the plaster was worn. Unna's paste, elastoplast, or " Viscopaste " bandages are suitable for long cases, and crepe bandages for milder and shorter cases.

In contradistinction to this group of patients in whom there is a controllable œdema, usually of the lower limb and lasting only for a short time, while the vascular tone returns to normal, there is a rarer but more troublesome group of persistent œdemas. These may be secondary to a number of causes.

CHAPTER VII

THE TREATMENT OF WOUNDS

APART from compound fractures wounds are commonly associated with fractures, and the two must often be treated simultaneously. The assurance of primary union in a wound is always important, and doubly so if the wound communicates with a fracture. A detailed description of the treatment of wounds is thus not only a part of the description of the treatment of compound fractures, but it is deemed sufficiently important to merit a chapter to itself. We shall deal first with the simple wound in which there is no skin loss. Wounds in which there is loss of skin, or threatened loss of skin, may present a very complicated problem, primarily the field of the plastic surgeon. Some understanding of the principles of treatment is necessary to the traumatologist, and these will be discussed in more detail in the chapter on compound fractures, though the principles remain the same whether a bone is broken or not.

The history of the treatment of wounds from the days when pus was "laudable" to the days when it became "damnable" is the history of surgery itself. Mediæval superstition first shows the impact of common-sense observation with Ambroise Paré's description of the improved condition of the soldiers whose wounds he had been unable to cauterise. From this time on we can trace a gradual development of modern principles, first one man grasping one aspect of treatment, and making a name for himself, only to be forgotten as another achieves successful results by his discovery of another important principle. The synthesis of a completely rational outlook on the subject has thus been the product of many minds, in which few stand out as milestones. With the discovery of bacteria by Pasteur, and the development of antisepsis by Lister, we approach the era in which the First World War was fought. The object at this time was the elimination of bacteria by the use of antiseptic media. Wounds as a result were treated by the introduction of a solid and persistent antiseptic such as B.I.P.P. or an attempt to keep them clean was made by continuous irrigation as in the Carrel Dakin method. The frequent dressings employed were distressing to patients and nurses alike, and the tired and exhausted faces of the patients contrasted markedly with the odourous but cheerful and trolley-free wards of the modern fracture unit.

The change is not so much to be attributed to the end of the antiseptic era as to the end of a campaign for the recognition of the defensive powers of the body when aided to the utmost by surgical ability. To this has been added the new weapon of chemotherapy, which gives just the little time longer for the body to organise its [illegible]ences, which may make all the difference in the loss of life or the

may be altered for a period now and then by a course of sodium citrate or phosphate. In likely cases the renal tract should be watched by X-rays.

When developed a number of cases will be found to absorb on assuming the upright posture. Others will continue to develop or produce symptoms which will demand their surgical removal.

FURTHER READING

Myositis Ossificans

BOWERS, R. F. "Myositis Ossificans Traumatica," *J. Bone and Joint Surg.*, 1937, 19, 215.
BRISTOW, R. "Myositis Ossificans," *Brit. J. Surg.*, 1922–23, 11, 475.
THORNDYKE, A. "Myositis Ossificans Traumatica," *J. Bone and Joint Surg.*, 1940, 22, 315.
GESCHICKTER and MASERITZ. "Myositis Ossificans," *J. Bone and Joint Surg.*, 1938, 20, 661.
MORLEY. "Traumatic Myositis resulting from Gunshot Wounds," *Brit. J. Surg.*, 1919, 7, 178.

Myositis Fibrosa (Volkmann's)

BROOKS. "Pathologic Changes in Muscle as a Result of Disturbances of Circulation," *Arch. Surg.*, 1922, 5, 188.
GARBER, J. N. "Volkmann's Contracture as a Complication of Fractures of the Forearm and Elbow," *J. Bone and Joint Surg.*, 1939, 21, 154.
GRIFFITHS, D. L. "Volkmann's Ischæmic Contracture," *Brit. J. Surg.*, 1940, 28, 239. (Able article, accompanied by full references, supporting the arterial theory of origin.)
JONES, ROBERT. "Volkmann's Ischæmic Contracture," *Brit. M. J.*, 1928, 2, 639.
GRIFFITHS, D. L. "Certain Vascular Lesions." Modern Trends in Orthopædics." Butterworth, London, 1950, Chap. 13, 360.

Acute Traumatic Bony Atrophy

SUDECK. "Uber die akute enzundliche Knochenatrophie," *Arch. f. Klinische Chirurgie*, 1900, 62, 147.
OPPENHEIMER. "The Swollen Atrophic Hand," *Surg. Gynec. and Obst.*, 1938, 57, 446.
FRAZER-GURD. "Post-traumatic Acute Bone Atrophy," *Ann. Surg.*, 1934, 99, 449 (With further references.)

Nephrolithiasis

PULVERTAFT. "Nephrolithiasis occurring in Recumbency," *J. Bone and Joint Surg*, 1939. 21, 559.

these risks. Any interference with the wound must be carried out under strict aseptic conditions. Some wounds in which infection is developing must not be closed, but lightly packed and enclosed in a plaster cast.

The practical points which are determined by these principles will now be discussed.

1. TIME. The time factor already mentioned must be enlarged upon. The earlier the treatment of a wound under surgical conditions the better, but it has been found that treatment can be carried out with benefit many hours after the infliction of the wound. The absolute limit of time at which it can be carried out cannot be stated, but is somewhere between thirty-six and forty-eight hours. Joints, whose importance merits complete treatment, are very resistant to infection and show a satisfactory response to adequate debridement, suture of the synovial membrane and drainage down to the suture line, twenty-four to thirty hours after wound infliction. The use of chemotherapy has been in part responsible for the ability to interfere effectively later than was thought wise before. A wound adequately treated with penicillin and sulphonamide in a patient who has had adequate parenteral chemotherapy, will be less seriously infected on arrival at the theatre, and a wound more seriously infected will be given a breathing space after excision in which to organise its defences. *In dirty, late, untreated wounds treatment is limited to* removal of foreign bodies and the excision of dead tissue to improve drainage. Local and general chemotherapy are then continued.

2. ANTISEPTICS. The application of any chemical substance or solution other than normal saline, or small quantities of the chemotherapeutic drugs, to the walls of a wound which is to be sutured is to be condemned. They can do nothing but harm. If watery, they increase the œdema of the tissues, which absorb water; if hyperosmotic, such as spirit or iodine, they are equally dangerous to the cells by dehydration. On the surfaces of a wound to be excised they are less open to objection. Iodine is a useful antiseptic for the skin, but in the wound it must be used sparingly. The use of a moist swab dripping with iodine is to be avoided, but a well wrung out swab has the advantage of dyeing the damaged tissues a deep brown while viable tissue remains a pale yellow. The use of a "frosting" of sulphonamides and penicillin on the wound surface is *not strictly to be compared to the use of an antiseptic.*

3. DRYNESS. In order to combat the development of bacteria which flourish in a moist medium it is advantageous to keep the wound as dry as possible under all circumstances. It is further important in encouraging clotting. This fundamental will be referred to again, but it is placed here on *account of its importance,*

loss of a limb, in the severely wounded. The essential principles remain the same whether chemotherapy is used or not, and will not be altered by any additions to the armoury. Each point in technique is directed towards reducing the available nutrient material for bacteria, and assuring that the wound cavity is lined with viable cells among which no pocketing or pressure of retained products can develop. The principles concerned will be pointed by the discussion of their practical application, but may be theoretically set out as follows.

1 TIME. The stabilisation of the defences of a wound occurs in thirty-six to forty-eight hours. After this time any interference with a wound which is at all extensive may open up new paths for the spread of infection. Bacterial infection is lowest immediately after the infliction of a wound, and it therefore follows that this is the best time for surgical treatment, and with increasing delay it becomes less and less propitious, till when defence and infection are balanced it becomes unwise

The delay in the occurrence of serious infection which is produced by adequate general and local chemotherapy, permits much later interference with a wound than used to be thought safe. Postponement of immediate treatment may be necessary because of general shock, or inadequate facilities, and delays of twenty to thirty hours may occur without evidence of it having prejudiced the result of wound healing Similarly a patient requiring extensive attention, may safely have the attention staged at forty-eight hour intervals, to avoid adding to the post-traumatic shock

2. REDUCTION OF BACTERIAL MULTIPLICATION. The avoidance of further soiling of the wound is merely common sense. The more subtle part of surgical technique is the deprivation of the bacteria of any nutrient media For this reason the soiled walls of the wound are excised and damaged tissues removed. Hæmostasis must be perfect, for clotted blood becomes a fine breeding ground, and excessive moisture is to be avoided as being equally necessary to bacterial reproduction

3. AVOIDANCE OF BACTERIAL SPREAD The spread of organisms is aided by the movement of tissue planes on each other preventing a fixed line of granulation tissue defence being formed It is therefore essential whether the wound is accompanied by a fracture or not that the movement of the tissue planes on each other should be restricted. This is accomplished by gentle tissue pressure on bandaging the limb, and the support of a splint usually a plaster cast The pressure of retained products and the re-infection of the wound with fresh strains of organisms may also be important. Drainage of the wound, and its enclosure in a plaster cast may help to avoid

is unnecessary unless the part is particularly hairy. Even in the scalp close clipping is satisfactory. The wound is then packed with sterile swabs (Fig. 43) and the surrounding area of skin cleaned, wiping *away* from the wound. Soap is first used, this is washed off with water or saline and the skin then dried. A final application of spirit or iodine completes the preparation. The wound swabs prevent contamination of the wound with the washings and the exuda-

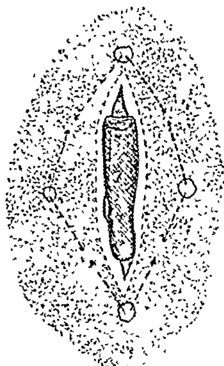


FIG. 44. With a roll of gauze still in position the skin almost up to the edges of the wound is painted with iodine. Small blebs are raised in the skin with local anæsthetic, and then the edges of the wound infiltrated by injections along the lines indicated by the arrows.

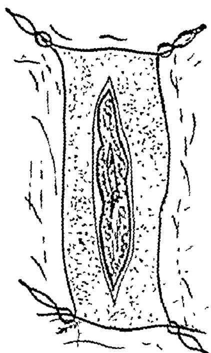


FIG. 45. The protective gauze roll is now removed. The area is towelled. The shaded area indicates the margin of skin on the edge of the wound which is excised.

tion of blood which makes cleaning impossible. At the end of the skin toilet the swabs are replaced by fresh ones and the limb wrapped in a sterile towel In many cases an Esmarch's bandage, by producing complete hæmostasis, facilitates the identification of injured tissues, and their accurate debridement, and should now be applied over the towel After cleaning the wound, it is released and hæmostasis effected The surgeon then scrubs up preparatory to the complete excision of the wound. The towelling off of the area is completed and the removal of the swab is the first step before commencing.

5. LOCAL ANÆSTHESIA For most small wounds this is very

and that an early paragraph may be used to cry out against the prevalent practice of soaking a wound as soon as it is seen in a solution of acriflavine, saline or water. This can do nothing but harm. Firstly, it washes more dirt as a rule into the wound than out of it. Secondly, it results in the death of the living cells on the surface of the wound, which absorb the water by osmosis and burst their cell membranes. Further absorption in the wound makes it œdematous and this favours bacterial multiplication. To these points may be added the washing away of the blood which is bactericidal for a short time, and the increase in blood loss if the water is warm, and so dilates the blood vessels. If strong antiseptics are used the damage may be more serious. All these points are potent arguments against the use of water in any form near a fresh wound, and it will be found that a casualty department working on the dry principle will reduce the incidence of infected lacerations by 30 to 40 per cent.

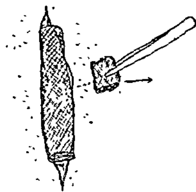


Fig. 43. Cleaning up a wound. A roll of gauze is placed in the wound, and the skin cleaned away from the edges of the wound with a swab held in forceps.

A wound when freshly seen should have any very gross dirt wiped away from it by dry gauze, and then have a dry gauze dressing applied to it till the case can be taken to a theatre and the correct treatment instituted. Should the wound be hæmorrhaging seriously a tourniquet may be applied, or the vessel caught with forceps if it can be seen, or the pressure of the dressing may be relied upon to stop it.

4. Preparation points. The use of a clean set of dissecting instruments for every major wound is essential and for every minor one desirable. The disturbance of the patient by transfer to the ward, from stretcher to bed, undressing, bed to stretcher, and finally stretcher to theatre table is best avoided by sending the patient to the theatre at once, and utilising the anæsthetic room as resuscitation ward. With large numbers of injured the use of a multi-bedded resuscitation ward amply proves its value. The preparation of the skin for operation, and the final removal of clothes can often best be done under the operation anæsthetic. Under certain circumstances it may be desirable to use a small injection of pentothal in the ward if there is to be much pain or disturbance of the patient.

A separate preparation trolley should be available containing a bowl of ether soap, a bowl of methyl-ether if the contamination is greasy, a bowl of sterile saline, iodine or spirit. Shaving the skin

become infected, are best left to a set operation when the wound has healed and merely tacked down to avoid retraction. In clean wounds nerves and tendons should be sutured. In wounds which are to be left open they may be tacked down to avoid retraction. Risk of damage to nerves from excessive local use of sulphonamide or penicillin, should be remembered.

8. HÆMATOMA. This must be reduced to the minimum possible by the careful suture of the wound, in which deep tension sutures will play an important part. Where it is impossible to stop oozing a small drain must be placed in the wound. The choice of the site for drainage must depend on the shape of the laceration, the most dependent point, and the site of the laceration. It is not always wise to drain through the wound itself, and a small puncture wound at a chosen spot in a skin flap is often more satisfactory. Where only a small amount of oozing is expected a few strands of folded silkworm gut will be a sufficient drain. For larger drainage some rubber dam may be used. Such drains should be removed at the end of twenty-four hours.

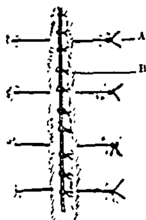


FIG. 46. The finished suturing, showing the everted skin edges.

A. Vertical mattress sutures.
B. Finer suture for close approximation of the skin edges.

9. SUTURING. Of the many materials suitable for suture the most satisfactory will be found to be silkworm gut, stainless steel wire, or waxed thread. Such sutures are strong, non-absorbable, but above all, non-absorbent, and do not carry moisture and with it infection from the surface into the deeper tissues.

It is extremely important that the skin edges be brought as closely together as possible, that the blood may clot between them rapidly and so seal the deeper layers of the skin off. One of the most satisfactory sutures is a vertical mattress suture passed deeply through the tissues on either side and then back through the skin edges and tied. Such a suture obliterates any space which may be present in the tissues by pressure and at the same time brings the skin edges accurately together, while slightly everting them, so that there is no infolding and accurate apposition is possible. It also relieves the skin edge of strain and exerts sufficient pressure on the subcuticular vessels to control hæmorrhage. The appropriate number of these stitches for a wound varies with the type and site of the wound. No fixed distance can be given, the number being determined by the readiness with which the skin is approximated, and sufficient being inserted to get the accurate apposition required. In between the mattress suture a few

satisfactory. A nerve block is to be preferred, as this avoids adding to the œdema of the wound, and the local anæsthetic may reduce the effectiveness of any chemotherapy for a short time The value of the injection of local anæsthetic into a fracture in the treatment of shock must not be forgotten. Local anæsthetics are time consuming and unsuitable for large wounds, or multiple wounds.

Local Technique. With a fine hypodermic syringe weals are raised on the iodined skin $\frac{3}{4}$ to 1 inch from the wound edge, at spots appropriate to the infiltration of the edges of the wound. Novocaine, 1 to 2 per cent., is satisfactory, and it is better not to add adrenaline to it. Excess local anæsthetic entering the tissue spaces washes out of the wound, but this is washing the debris in the right direction, out of the wound. Under no circumstances is the needle entered into the tissues through the wound surface. In spite of the increased water content of the tissues near the wound local anæsthetic does not make the wound sodden as there is no cell destruction and it is rapidly absorbed. No adverse influence on healing can be detected. The wound surface is now anæsthetised, and if desired it can be lightly painted with iodine before towelling the wound up preparatory to excision.

6. Excision of the wound We are concerned here primarily with the small wound. The details of tissue excision in the larger wounds will be found on p. 119. Skin is extraordinarily resistant to infection, and should be preserved. Excision of the skin edge is generally unnecessary. It may be required because the skin edge is ragged or crushed, or to obtain a better scar. The smallest amount of skin consistent with the result desired should be removed.

In most areas, particularly the scalp, this can best be done with the knife, but in certain areas where the skin is fine the scissors will be most useful. Where possible the incision will be carried through the subcutaneous fat to the fascia, so that the whole soiled surface of the skin and subcutaneous fat is excised at once.

Loose tags of fibrous tissue, tendon, and muscle will be seen and excised, till all the tissues seen have a fresh and clean appearance. In perforating wounds it will be necessary to enlarge the skin wound to allow it to be explored to the bottom This is essential to avoid leaving foreign bodies in the depths of the wound.

7. Avoidance of buried foreign bodies. Not only must no debris be left in the depths of the wound, but it is advisable not to leave any catgut or other suture material buried in the wound unless it is absolutely necessary This can usually be avoided, unless a large vessel is cut, by the judicious use of deep silkworm tension sutures. Tendons, in a wound which cannot be closed or is likely to

is dry and satisfactory at the end of this period then some movement may be allowed, but if there is any suspicion of infection or moisture it is kept at absolute rest.

A further important point is the avoidance of swelling. This is best done by elevation of the part. An injured leg is rested on a Braun's splint in bed. Arm injuries if mild may be merely kept recumbent, but if there is a serious lesion of the forearm Zeno's position should be used (Fig. 271).

11. Fresh air to the wound. It is essential for sound clotting on the skin that the blood poured out be able to lose some of its water content. The necessity for a dressing for the first hour or two has been emphasised, but after this the wound is best exposed to

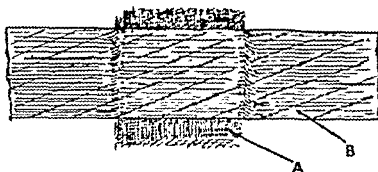


Fig. 49. The correct method of applying strapping dressings to provide ventilation. A = Gauze. B = Strapping.

the air. If the limb is in plaster, a window may be cut, but plaster being porous allows very satisfactory circulation of air, and unless the discharge is profuse, windowing is unnecessary. Under no circumstances should an airtight dressing be applied as may easily be done if strapping is not carefully used. Oily dressings should never be used if primary union is anticipated. This, of course, applies only to wounds which can be closed.

If these comparatively simple rules are followed it will be found that the number of septic wounds in any casualty clinic is greatly reduced with a corresponding absence of stiff fingers, granulating wounds, and persistent sepsis, which wastes so much of the time of a casualty department.

Chemotherapy

J. D. Allan Gray, T.D., F.R.C.P.E., D.P.H.

The opportunities provided by the war have enabled the chemotherapeutic agents to establish themselves on a rational basis in much less time than many equally revolutionary innovations. They have been viewed by some as a return to the era of antisepsis, but

smaller stitches are placed to bring the skin edges into still more complete apposition. Suturing under any great tension is to be avoided. The relaxed position of the limb, undercutting the flaps, and appropriate incisions may make the union of the skin easier. When the wound is sutured it is dried well with a swab wrung out in spirit, and a dressing of dry gauze applied to it and bandaged on. The use of an air-tight dressing such as strapping completely covering the wound is to be condemned as it keeps the wound moist. Strips of strapping over gauze have not this objection. There is not always the necessity for a bandage dressing, but it helps to control oozing and absorbs the discharge which occurs in the first few hours. In small

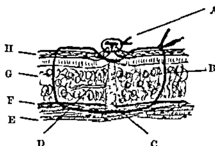


FIG. 47. Diagrammatic section of the sutured wound.

A. Fine approximating suture.
B. Deep mattress suture for retention and hæmostasis.
C. Hæmatoma.
D. Small blood vessel controlled by the mattress suture
E. Muscle
F. Fascial sheath
G. Subcutaneous fat.
H. Skin.



FIG. 48. Padded wire finger splint bandaged in position to immobilise the fourth finger after a compound fracture of the terminal phalanx.

wounds this is unnecessary and sticking one or two layers of gauze over the wound with Tinct benzoin co or mastisol is sufficient. If a bandage is used it should be removed in four to six hours and the wound left exposed to the air.

10. ABSOLUTE REST In order to avoid disturbance of the tissue spaces which are being repaired, and the formation of fresh hæmatomas in the wound absolute rest is essential. Inadequate fixation is useless, and it will be found that in the majority of cases only plaster gives that immobilisation which is necessary. This absolute immobilisation does not need to be maintained for more than forty-eight to seventy-two hours as a rule. If the wound

is dry and satisfactory at the end of this period then some movement may be allowed, but if there is any suspicion of infection or moisture it is kept at absolute rest.

A further important point is the avoidance of swelling. This is best done by elevation of the part. An injured leg is rested on a Braun's splint in bed. Arm injuries if mild may be merely kept recumbent, but if there is a serious lesion of the forearm Zeno's position should be used (Fig. 271).

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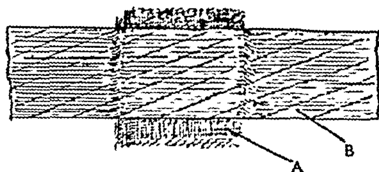


Fig. 40. The correct method of applying strapping dressings to provide ventilation. A = Gauze. B = Strapping.

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Chemotherapy

J. D. Allan Gray, T.D., F.R.C.P.E., D.P.H.

The opportunities provided by the war have enabled the chemotherapeutic agents to establish themselves on a rational basis in much less time than many equally revolutionary innovations. They have been viewed by some as a return to the era of antisepsis, but

their action is far more subtle than the sledge hammer blows of mercury or carbolic.

The essential indications for the use of chemotherapy for fractures are either the infection of the fracture or its contamination such as to render its infection extremely probable. Compound fractures and fractures of the base of the skull penetrating into the nasopharynx or ear fulfil these conditions. In addition, prophylactic chemotherapy may be indicated to prevent or control infection of the lung in elderly or debilitated patients in whom the fracture may have necessitated an anæsthetic or a prolonged stay in bed.

Sulphonamides

Numerous derivatives of sulphanilamide (*p*-aminobenzene sulphonamide) are used in medicine. Those which are slow to be absorbed from the bowel are reserved for their local action for intestinal infections. Those easily absorbed are used in surgery and include sulphathiazole, sulphadiazine and sulphamerazine. These three are combined in sulphatriad which is used for the same conditions as its constituents and is less likely to cause crystalluria.

The sulphonamides neither stimulate the defence mechanisms nor destroy the bacterial toxins. On susceptible organisms their action is bacteriostatic rather than bactericidal and they therefore give the defence mechanisms time to destroy them. For normal multiplication, organisms absorb *p*-aminobenzoic acid into their enzyme systems. An organism acted on by a sulphonamide has its enzyme system blocked by the sulphonamide and so it cannot reproduce. As the enzyme system has a greater affinity for the *p*-amino benzoic acid than for the sulphonamide, the latter must be present in a greater concentration. Effectiveness of the sulphonamide therefore depends on its availability and concentration and is reduced by pus, necrotic tissue and the *p*-aminobenzoic acid contained in some local anæsthetics such as "novocain," "larocain," "tutocain," "butyn" and "anæsthesin." Fortunately, there are other anæsthetics (cocaine, tropacocaine, "eucaine," "stovaine," "nupercaine," phenacaine, "decicaine," "metycaine" and amethocaine) which do not contain *p*-aminobenzoic acid and therefore do not antagonise the action of the sulphonamides. The introduction of antibiotics, however, has lessened the need for the combined use of sulphonamides and local anæsthetics.

The organisms likely to invade the site of a fracture vary widely in their susceptibility to sulphonamides. Thus β-hæmolytic streptococci are highly susceptible ; staphylococci are markedly less so and the gram negative bacilli, including *Bact. coli*, *Ps. pyocyanea* and *Proteus* are quite resistant. For hæmolytic streptococci, sulpha-

nilamide is the sulphonamide of choice, but for staphylococci and the clostridia of gas gangrene, sulphathiazole is much more active.

The sulphonamides are used for both prophylaxis and treatment of infections. The doses for prophylaxis are much less than for treatment. Whether one has been applied to a wound as part of first aid treatment or not, sprinkling in the operating theatre of sterilised sulphanilamide powder into the wound after its excision or other surgical procedure greatly reduces the chance of infection. The maximum amount should not exceed 15 grammes and usually much less suffices. It is convenient to have 5-gramme amounts of the drug weighed out and all preparations intended to be inserted into wounds must be sterilised and applied from sterile containers. The application is much easier in wounds with wide exposure of damaged tissues than in deep wounds with small apertures. For the latter, a 15 per cent. suspension of sulphathiazole may be used except in the immediate vicinity of large nerves. The wound must never be packed with the solid drug lest a hard foreign body of the drug be produced. The topical application should not be carried on for longer than five days. When the wound is septic, the application is recommended of a sulphonamide such as sulphathiazole with 1 per cent. " sulfracin " (aminacrine hydrochloride). In fractures involving the brain, sulphonamides and particularly sulphathiazole should not be used as they may cause epileptiform convulsions which may be fatal. Sulphadiazine is, however, less likely to produce such convulsions. The local application gives a much higher concentration than oral administration, which alone is not usually sufficient to clear the bacteria from granulating wounds. After a thorough local application further sulphonamides are not usually given systemically for the twelve to twenty-four hours following for fear of producing a dangerous blood level. If, however, signs of gas gangrene appear, systemic treatment should be commenced immediately, the dose being reduced by half the amount which has been applied locally.

Apart from topical application, the oral route is the usual method of administration of sulphonamides, parenteral administration being resorted to only for speed in fulminating infections or when the oral method is impracticable, as in vomiting. The sulphonamides are dispensed in tablets of 0·5 grammes. An adult with a moderate infection is treated with 2 grammes immediately and 1 gramme every four to eight hours for six or seven days. In severe infections, 2 to 4 grammes of soluthiazole may be given intravenously. Weight for weight, children tolerate sulphonamides better than adults. The idea that sulphur, either in food, drugs or aperients should be avoided during sulphonamide treatment is outmoded, but the fluid intake during treatment should be generous.

For children the dosage may be calculated by multiplying the adult dosage by $\frac{\text{age,}}{15}$ remembering that the young tolerate the drug very well, and that at the ages of one to three the calculated dose should be doubled.

Provided the doses are adequate, the results depend mainly on

the sulphonamide sensitivity of the infecting organism. Occasionally however, absorption may be poor; a complication may develop; the drug may be excreted unduly rapidly or the patient's defence mechanisms may not react adequately. Failure to respond to oral administration may yield dramatically to an intravenous injection.

Sulphonamides, even in therapeutic doses, may produce toxic effects such as cyanosis, nausea and vomiting, toxic nervous effects, pyrexia, rashes, blood dyscrasias, nephrosis and hepatitis. Cyanosis, depression and confusion, nausea and vomiting may follow sulphapyridine occasionally and sulphathiazole rarely. These all cease if the drug is withdrawn. When sulphapyridine causes vomiting, it can usually be replaced by another sulphonamide. Pyrexia, sometimes followed by varying types of drug rashes, conjunctivitis, and swelling of the joints, usually indicates a sensitisation to the sulphonamide. If the sensitisation has not been provoked by a previous administration of the sulphonamide it does not usually appear before the tenth day of treatment. It may be specific to the compound which provoked it or it may be common to different sulphonamides. It usually persists long after the cessation of treatment. Desensitisation can be accomplished by very small and gradually increasing doses.

A mild leucopenia is not unusual early in the treatment, but the white blood count should not fall below 4,000 nor the polymorphonuclear leucocytes below 50 per cent. In contrast, a leucopenia occurring about the tenth day of treatment signifies dangerous agranulocytosis. An acute hæmolytic anæmia may start about the third day. In addition to the withdrawal of the drug, fluids, alkalies, and transfusions may be required. Very occasionally, sulphonamide treatment is associated with an aplastic anæmia and thrombocytopenic purpura, a toxic hepatitis with exfoliative dermatitis or a true nephrosis.

Crystals may be deposited in the urine during treatment with many different sulphonamides and give rise to abdominal pain, oliguria and macroscopic hæmaturia. Although there are numerous predisposing factors, the condition can be prevented by ensuring a sufficient fluid intake, especially if much fluid is being lost in vomiting, diarrhœa and sweating. The minimum intake for an adult without excessive loss is 6 pints every twenty-four hours. Alkalies help to prevent the deposition of crystals of sulphathiazole, sulphadiazine and sulphamerazine or their acetyl compounds, but have no influence on sulphapyridine. The use of mixtures of different sulphonamides such as sulphatriad in the same doses as used with one compound keeps the concentration in the urine of the individual constituents so low as to make crystalluria unlikely. If

anuria occurs and is not due to a nephrosis, cystoscopy and ureteric catheterisation may be required.

Antibiotics

The discovery of penicillin by Sir Alexander Fleming in 1929, is one of the most dramatic chapters of modern medical history. If its discovery was the flash of genius, its re-discovery and evaluation by Sir Howard Florey and his co-workers represents the more patient side of medical research. It is an invaluable ally against infection of wounds, particularly the compound fracture.

In general medicine and surgery, some conditions can be confidently treated with an antibiotic without laboratory investigations to identify the infecting organism or to estimate its sensitivity to the antibiotic. In contrast, the organisms which infect fractures are so varied, especially in their sensitivities to the different antibiotics, that treatment based on clinical diagnosis alone may be of limited value and once the site of a fracture has become infected bacteriological investigation is an essential prerequisite of rational treatment. For this it is preferable to obtain the specimens before chemotherapy is begun. Not only must the organism be isolated and identified but frequently its sensitivity to different antibiotics must be determined. This is necessary because staphylococci, for instance, vary widely in their sensitivity to penicillin, streptomycin, chloramphenicol, aureomycin and terramycin. On the other hand, hæmolytic streptococci and *Cl. welchii* may be assumed to be extremely sensitive to penicillin. When the infection is a mixed one, the sensitivities of all the pathogens present should be estimated in the hope of identifying one antibiotic to which they are all sensitive. The only certain test of whether an antibiotic is appropriate for the condition is its clinical trial. Laboratory tests may be misleading for small changes in cultural conditions may easily upset the routine sensitivity tests. Usually, however, there is a close correlation between *in vitro* and *in vivo* results. Admittedly, an organism which appears to be sensitive *in vitro* may not respond to the antibiotic *in vivo*. This may be due to the presence of a mutant more resistant than the individual organism selected for the laboratory test. Fortunately, the lack of correlation may also be in the opposite direction for an antibiotic may be successfully used against an organism which on the laboratory tests would be regarded as resistant. This may be due to the combined action of the antibiotic and the immunity of the body, or it may be occasionally effected by subjecting the organism to a very high concentration of the drug through topical application. If the infection is not overcome quickly, all these bacteriological

investigations may have to be repeated, as both the organisms and their sensitivities may be completely altered.

Three difficulties are becoming increasingly evident in the use of antibiotics : (1) the development of sensitisation of the patient and handlers of drugs, (2) the development of resistance of the organisms, and (3) the changes in the balance of a mixed flora.

(1) Sensitisation of the patients and handlers of antibiotics usually first shows itself in lesions between the fingers and round the eyes. Later it may manifest itself as serum sickness, joint pains, asthma, urticaria, exfoliative dermatitis and even encephalitis. In patients it should be obviated as much as possible by using the drugs only when there is definite justification for them. Oral administration of an antibiotic is less likely than injection to produce sensitisation. Pharmacists and nurses should wear rubber gloves and face masks with cellophane visors, use exclusively syringes which do not leak, and not allow the antibiotic solution to be sprayed into the air. Regular patch testing of these individuals is also recommended. For the treatment of one of these severe reactions, antihistamine drugs are used. Later, desensitisation may be attempted by small daily oral or intramuscular doses gradually increasing. The course may take seven weeks to complete.

2. The development of resistance of organisms originally sensitive to an antibiotic is becoming increasingly common. For instance, the incidence of staphylococci now found to be resistant to penicillin and streptomycin is steadily increasing. There is also a tendency for cross-resistance to develop and this may jeopardise the use of alternative antibiotics. Erythromycin is usually active against penicillin-resistant staphylococci but it is very apt itself to incite drug resistance.

3. The balance of a mixed flora may be radically disturbed by an antibiotic. When an organism sensitive to the antibiotic is suppressed or removed, the resistant ones may grow abundantly. Thus after the use of even only penicillin or streptomycin, far less a broad-spectrum antibiotic, a thrushlike condition may develop in the mouth. This may be partly due to avitaminosis and may respond to spraying with vitamin B_{12}. But much more serious, after the use of chloramphenicol or aureomycin, a moniliasis may develop in the lung, the intestine or the urinary tract or a staphylococcal enteritis may develop. These serious effects, however, should rarely be produced by the amount and duration of the antibiotic treatment required for fractures. To try to prevent the moniliasis occurring, a capsule containing 0·44 grammes of undecylinic acid has been given orally for each 250 mg of the antibiotic used and for the treatment of the staphylococcal enteritis, erythromycin is the drug

of choice. Prolonged administration of penicillin for a fracture of the skull may predispose to a meningitis due to *Ps. pyocyanea* which thrives on that antibiotic. This infection is less likely to occur if sulphonamides are given simultaneously with the penicillin.

Penicillin. The preparations now available in Great Britain include

Benzylpenicillin (crystalline penicillin G.).
Procaine penicillin (procaine penicillin G.).
Benzathine penicillin.
Benethamine penicillin.

Benzylpenicillin is very soluble in water but the solution is unstable. The solution should therefore be used freshly made but if it must be kept, it should be kept in a refrigerator. Procaine penicillin is less soluble and its solution is also unstable. Benzathine penicillin and benethamine penicillin are relatively unsoluble. Their solutions, however, are much more stable and they are supplied by the manufacturers as liquids. The doses are measured in arbitrary " Oxford units."

For parental use, Benzylpenicillin is supplied as a powder in vials of 100,000, 200,000, 500,000 units and 1, 5 and 10 megaunits (1 megaunit equals 1,000,000 units). When kept dry it remains stable for many months even in the tropics. For treatment, the dosage should be regulated to maintain a satisfactory level in the blood. An injection of benzylpenicillin produces a high blood level for a short time and has therefore frequently to be repeated. In contrast, an injection of one of the less soluble preparations produces a lower concentration for a much longer period.

Intramuscular injections are occasionally followed by severe and even fatal reactions. These should not deter one from giving injections when indicated, but precautions should be taken to ensure that an injection intended to be intramuscular is not given into a vein, and that adrenaline and antihistamines are available should a sensitivity reaction develop. These sensitivity reactions are probably more common after procaine penicillin, which has a larger molecule than the soluble substance. In fractures of the skull, the intrathecal administration of penicillin in doses over 200,000 units should be avoided for fear of producing status epilepticus, paralysis and even death.

For oral administration, benzylpenicillin and benzathine penicillin are supplied in both tablet and liquid form. The blood levels obtained are unreliable. Benzylpenicillin packs each contain 10, 12 or 20 tablets, each usually containing 200,000 units. Benzathine penicillin packs contain 18 tablets of the same amount. The containers must be able to exclude water vapour during storage, as dampness causes the penicillin to decompose.

The recently introduced Penicillin V (or " Distaquaine V ") is acid stable and therefore suitable for oral use. Its spectrum is identical with that of Penicillin G and it is replacing treatment by injection.

Penicillin is also used locally as a dusting powder. Conspen is the name given to the sterile powder issued in a container holding 15 grammes of which each gramme has 5,000 units of penicillin.

There are also on the market preparations of penicillin with streptomycin for injection and of penicillin with sulphonamides for oral administration.

Penicillin has a high therapeutic value due to its high potency and non-toxicity. Apart from penicillin K, which is inactivated by plasma, penicillin is effective in the presence of blood or pus. It is active mainly against gram-positive organisms including cocci and clostridia, by preventing their division and by making them disintegrate. Some organisms such as *Bact. coli* produce penicillinase, a ferment which destroys penicillin and their presence in a wound may invalidate the treatment by penicillin of a penicillin-sensitive invader.

Streptomycin. Two preparations are available, streptomycin (usually as the calcium chloride complex) and dihydrostreptomycin.

Both are powders which remain potent for long periods. Their solutions, however, lose their potency within a week. They are never given by mouth as they would not be absorbed, but always by injection either intramuscularly or intrathecally. Both have a toxic effect on the vestibular and the auditory portions of the eighth nerve. The calcium chloride complex appears to produce vertigo and inco-ordination before it produces deafness and these tend to be less permanent. On the other hand, the dihydrostreptomycin tends to produce a permanent deafness as its first toxic effect. For these reasons, streptomycin is preferable to dihydrostreptomycin. In surgery, however, these toxic effects are not likely to be encountered for the drug is never likely to be used for sufficiently long periods. When the renal function is impaired, the drug may accumulate in the blood in a fatal concentration. For the short-term treatment of an acute infection the maximum safe dose in an adult is 1 gramme twice a day and this only for seven days.

Apart from tuberculosis, streptomycin is useful in the treatment of infections with gram-negative bacilli. Some penicillin resistant staphylococci have also been treated with streptomycin but usually one of the broad-spectrum antibiotics or erythromycin is used against them.

CHLORAMPHENICOL ("Chloromycetin") is issued in 250 mg. capsules and the maximum dose for a course of ten days has been laid down as 104 capsules. They are given by mouth. It can also be used as a dusting powder for infected wounds.

On rare occasions chloramphenicol may produce a fatal dyscrasia of the red or the white blood cells or both. Most of the reported cases have been due to prolonged overdosage. It cannot be too strongly emphasised that if chloramphenicol is to control an infection, it will do so within five days and continued administration will only expose the patient unnecessarily to the risk of a blood dyscrasia. A patient receiving chloramphenicol should be carefully watched for toxic effects, such as lassitude out of proportion to the infection, sore throat and hæmorrhagic rashes. If these occur, the chloramphenicol should be stopped and not recommenced. A daily white blood count does not usually give sufficient warning of the dyscrasia to be of practical value. Chloramphenicol can also produce a moniliasis in chronic suppurative conditions.

In surgery, chloramphenicol has only a limited place as its action there is confined to gram-negative organisms. The ease with which it traverses the blood-brain barrier makes it useful in certain forms of meningitis following fractures of the base of the skull.

CHLORTETRACYCLINE (aureomycin) is supplied in 250 mg. capsules for oral administration. For the adult of average weight the daily dose varies between ½ and 1 gramme and is usually divided into two or four doses given with either a meal or a copious bland drink. Even in therapeutic doses aureomycin frequently produces a distressing pruritis and diarrhœa. If the latter is prolonged, the intestinal wall may be permanently damaged. The toxic effects, however, are unlikely to be serious unless the drug is given to a patient with a chronic septic condition over a period sufficiently long as to produce a moniliasis. Aureomycin has a wide spectrum for both gram-negative and gram-positive organisms and is used with great success in coliform infections which are resistant to sulphonamides and streptomycin. It does not usually subjugate *Proteus* and certainly not *Pseudomonas pyocyanea*.

OXYTETRACYCLINE ("terramycin") is supplied in tablets of 50 mg., 100 mg. and 250 mg. for oral administration and can also be used intravenously and as a topical powder. The daily oral dose for an adult varies from 1 to 4 grammes divided into four doses. It produces very few side effects and has an even wider spectrum than aureomycin. It has been specially recommended for prophylactic use in the treatment of contaminated traumatic wounds and injuries involving the mouth. Animal experiments have suggested its use as a protection against gas gangrene.

TETRACYCLINE ("tetracyn" and "achromycin") is supplied in capsules of 50 and 250 mg. for oral administration, and it can also be given intravenously. The dose recommended for an adult is 1 gramme daily divided into four doses. It has an antibacterial activity similar to aureomycin and terramycin but is more soluble, more stable and has greater penetration. It may produce nausea, vomiting, diarrhœa and occasionally thrombophlebitis, but as its molecule is smaller than that of either chlortetracycline or oxytetracycline, it is less likely to sensitise and it is claimed to produce fewer unwanted side effects including staphylococcal enteritis. Its range resembles that of terramycin. The ease with which it is said to traverse the blood-brain barrier suggests that it may be particularly useful in fractures of the skull. Achromycin has been introduced only recently but thus far there has not been any record of the development of bacterial resistance to it.

ERYTHROMYCIN ("Ilotycin" and "Erythrocyn") is issued in 100 mg. tablets. The average dose is 100 to 300 mg. every four to

any chance of healing by primary intention. For large areas of abrasion the treatment must resemble that of a burn. After gentle cleaning with saline, penicillin cream, or penicillin, sulphonamide powder and "tulle gras" are applied and bandaged firmly on. Systemic penicillin is continued. Any infection of the area will need a change-over to hot saline compresses applied over the "tulle gras," several times a day, and with a dry dressing at night. The "tulle gras" is changed once a day only.

FURTHER READING

MATTHEWS, D. N. "The Surgery of Repair," 2nd ed., 1946 (Blackwell, Oxford, Chap. 2).

ANDERSON, D. P. "The Problem of Wound Healing," *Ann. Surg.*, 1938, 108, 918.

HARTWELL, S. "Surgical Wounds in Human Beings," *Arch. Surg.*, 1930, 21, 76.

TRUETA and BARNES. "The Rationale of Complete Immobilisation in Treatment of Infected Wounds," *Brit. M. J.*, 1940, 2, 46.

GARROD, L. P. "Recent Advances in the Antiseptic Treatment of Wounds," *Bull. War. Med.*, 1943, 3, 589. Useful summary with further references.

TRUETA, J. "The Principles and Practice of War Surgery," London, 2nd ed., 1944 (Wm. Heinemann and Hamish Hamilton).

"Penicillin in Warfare." *Special issue of Brit. Jour. Surg.*, 1944, *Vol.* 32.

CHAPTER VIII

THE MECHANICS OF FRACTURES AND OF THEIR INTERNAL FIXATION

Historical Note

After the first successful open reduction and suture of the patella, in 1874 by Lister, the door opened on a new vista in fracture treatment. Arbuthnot Lane saw farthest across this attractive prospect and saw more than most. His emphasis on the abnormal strains placed on a joint by mal-union is as important to-day as ever, and is the fundamental fact justifying operative interference. The popularity of Lane's methods were their undoing. Plating became the fashion, doomed by this to become unfashionable. So absurd were the lengths to which his methods were carried that a birth fracture of the femur in an infant was plated on the second day of life, with distressing results. The wholesale fixing of fractures under unsuitable conditions and with that lack of judgment and selection which had made Lane successful, made plating so unpopular that within fifteen years, to mention it in an examination, was to court disaster.

The return of operative methods to favour is based on sound convictions. It is to be hoped that the influence of those returning to such methods will prevent a further wave of unpopularity.

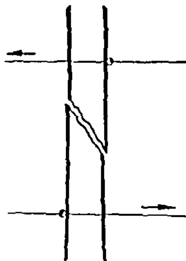


Fig. 51. Showing the method of reduction of an oblique fracture using beaded wires.

The mechanics of fractures. The displacements to which a fracture is liable are determined by its form, and this in turn determines the most appropriate form of fixation for that particular fracture. In particular the shape of the fracture determines the choice of method for internal fixation of the bone.

A fracture is liable to displacement in any of the three planes of space. Displacement may therefore be :—

1. Shortening.
2. Angulation.
3. Rotational deformity.
4. Side to side displacement.

The liability to displace in these directions is determined by the shape of the fracture of which there are three main types.

1. The transverse or part transverse fracture.

If the ends can be engaged, there is no risk of shortening, but angulation and rotation may occur, and side to side displacement is common. Angulation may be controlled by wedging the plaster (Figs. 592, 593).

If internal fixation is used a plate or an intramedullary nail must be chosen.

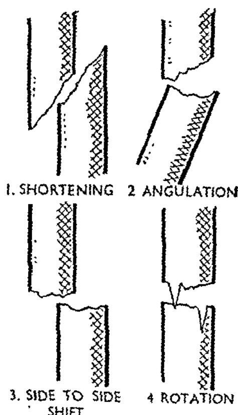


FIG. 52. Diagram to illustrate the possible displacements of fractures.

2. The oblique, or the helical (spiral) fracture.

This fracture always tends to shorten. If the obliquity is marked the pressure of the soft tissues on the sides tends to keep it in alignment, but rotation may readily occur and side to side displacement is common due to the inclusion of soft parts.

If internal fixation is used the fracture can be easily fixed by screws alone (Fig. 595).

3. The comminuted fracture.

This fracture tends to shorten and is very unstable. Skeletal traction or fixed distraction is therefore often required.

If open operation is used an intramedullary nail or a long plate bridging the comminuted area is needed.

Mechanical methods may be used in the reduction of the fracture or subsequently for retention. Thus transfixion wires may be used for distraction and the reduction of shortening in an oblique fracture, and subsequently incorporated in a plaster giving fixed distraction, which may be maintained till the fracture is firm enough for shortening to be unlikely In general, forcible fixed distraction is undesirable because of its influence on joints, and open reduction of the fracture and its fixation with screws would probably be the better method. The methods of mechanical assistance from which a choice has to be made are as follows :—

1. TRANSFIXION WIRES. These are drilled through specific bone

sites with a special drill (Fig. 125). The Kirschner wire is most commonly used. It has to be held tense with a special stirrup or tractor (Fig. 126). Its small diameter reduces the risk of infection around the points of entry, but makes it liable to cut through soft bone such as may be encountered in children or the aged. Although rigid in the tractor it is not so useful in controlling rotation as the more solid Steinmann's pin.

2. THE STEINMANN'S PIN. This is a pin of variable diameter (3-5 mm.) which can be bored through bone with a special handle (Fig. 127) or gently tapped into position. It is best used at the ends of bone where there is considerable cancellous tissue. Attempts to insert it through compact bone may result in fissure fracture unless the bone is drilled first.

3. BEADED WIRES. These are an interesting variation of the Kirschner wire (Fig. 51) and enable a certain amount of lateral pressure to be exerted on the fracture.

4. PARTIAL TRANSFIXION, BY PLAIN OR THREADED PINS. These pins are entered into the bone from one side and made to engage with the cortex on the opposite side. They can then be used as levers to replace the bone in position, and subsequently withdrawn, or incorporated in a plaster or attached by clamps to metal bars for retention. The use of crossed transfixion pins is common in fractures of the mandible, or on a larger scale in the Roger Anderson apparatus (Fig. 60).

5. THE ENCIRCLING BAND. This may be of wire, or a special band such as the Parham's band may be used. Special apparatus for tightening it is required. It is mechanically inefficient in all but long oblique or spiral fractures and its use here has been superseded by the screw.

6. THE SCREW. Screws have the advantage of producing strong fixation with minimum bulk of material where it is possible to use them alone. They may be supplemented with plates. Two main designs of screw are available :—

(*a*) Machine thread (Sherman pattern) ;
(*b*) Wood thread (Venable pattern).

In the latter screw the depth and width of the thread enable a better grip to be obtained on cancellous bone. In compact bone both screws are equally efficacious if the compact bone on the opposite side is penetrated by the screw. The Venable pattern screw is the more generally useful pattern. Screws should be accurately gauged, and a drill one-sixty-fourth to one-thirty-second of an inch smaller be used to drill the preliminary hole. The length of the screw should be calculated as nearly as possible, but excess is often of little moment and may sometimes be nipped off.

Special screws have been designed for special purposes, *e.g.*, with a broader thread to get a better grip on the bone when there is traction on the screw, or to produce impaction of the fracture such as is desirable in fractures of the femoral neck.

7. PLATES. The use of plates and screws provides the most satisfactory method of rigid fixation. Against them are their bulk, their frequent unsuitability of design, and the fact that if not carefully applied they may hold the bone ends apart. The use of plates with slotted holes avoids this difficulty and a good type of plate is the Eggers plate (Fig. 57), which permits a variation in the angle and the distance of the screws. Lane's plates are badly designed and tend to break at the holes. Some modern designs have overcome this disadvantage.



FIG. 53. Plating gone mad—excessive plating in a comminuted fracture of the leg. From Arbuthnot Lane's book.

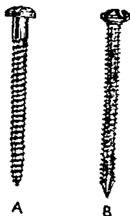


FIG 54. The two usual varieties of screws employed.
A. The venable screw with wide thread and taper end (Wood screw)
B The Sherman screw with self-clearing tip and fine thread (Machine screw).

8. WIRE. The early use of wire in fracture of the patella was found to be valuable, owing to its durability. Secondary changes were frequently noted around the iron wires used and silver wire often broke after a time Stainless steel wire is now available single or plaited, and is technically suitable for the few cases in which wire is advisable.

9. NAILS OR PINS. The most effective of these is the tri-fin pin of Smith Petersen used for fractures of the femoral neck (p. 474). But smaller pins and nails have been used in many other situations.

10. THE INTRAMEDULLARY NAIL OR WIRE. The use of strong Kirschner wires for intramedullary fixation has still an occasional place in fractures of the clavicle, dislocation of the acromio-clavicular joint and fractures of the forearm. In general it has given way to

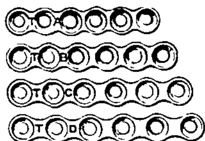


FIG. 55. Lane's Plate. The original design in which the holes were in alignment and the metal carrying them insufficiently strong. (*Down Bros.*)

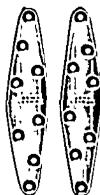


FIG. 56. Stamm's Plate. A plate designed to have greater rigidity in the centre and holes out of alignment. (*Down Bros.*)

the use of a stronger nail, which by its rigidity and grip on the inner surface of the cortex gives better fixation and permits early use of the limb. The best known of these is the rush pin.

KÜNTSCHER NAIL. This is a long, light, slightly flexible nail, inserted in the intramedullary cavity. Entrance to this is gained at one end of the bone, *e.g.*, the great trochanter in femoral fractures,

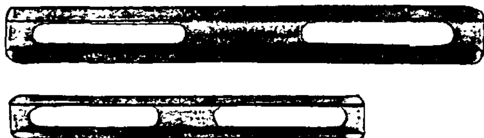


FIG 57. The slotted plate which permits end to end apposition of the bones and variable placements of the screws (Egger's plate).

the olecranon, the tibial tuberosity. The nail is sufficiently wide to press on the inner surface of the cortex and thus obtains good fixation by its width and excessive length. Open reduction and end-to-end apposition of the bones is usually a necessary preliminary. It is particularly helpful in the difficult fracture of the upper third of the femur. (Page 508.) Fractures of the tibia may also be readily dealt with, but these are satisfactorily controlled by the methods already available. For the upper extremity the method is a little

clumsy. Closed introduction is best, but where closed reduction can be achieved further treatment is often unnecessary. In open reductions the advantage of a smaller wound over the fracture is offset to a slight extent by the additional incision for introduction of the nail. Full assessment of the nail is dependent on its more general use.

Bone grafts or bone pegs may be used as a substitute for plates and screws when these are not available, or when the extra osteogenic power of the graft is required.

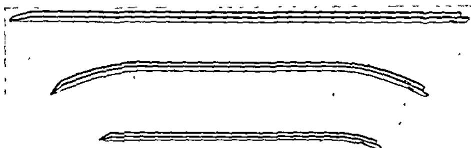


FIG. 58. Three varieties of the Kuntscher nail, the upper being used for the femur, the middle one for tibial fractures and the lower one for fractures of the forearm Other varieties with different cross sections have been developed and are perhaps more frequently employed.

Materials used in Internal Fixation

Difficulties arose with the early fixation of fractures by metal because of corrosion and electrolytic changes. These either weakened and broke the plate, inhibited new bone formation, or resulted in the formation of a sinus, at first discharging serous fluid, but along which infection was liable to travel.

Much experimentation has developed an answer to the problem in two forms, 18–8 S Mo. stainless steel, which is rigid and tough, and the alloy Vitallium, which is completely inert in the body, but which is cast and therefore more brittle, so that the screws may break under torsion Unfortunately the two materials cannot be used together without electrolytic action developing.

Having selected a suitable material attention must be given to the form of the material Some suggestions have been made about the design of plates Attention must also be paid to the type of screw head. The screw driver is liable to slip off the single slot of the ordinary screw, and screws with a cross head and a cross ended screw driver avoid this difficulty.

Drills one- or two-sixty-fourths of an inch less in diameter than the screw should be used. Occasionally where it is wished to approximate two fragments of bone it is wise to enlarge the nearer drill hole

so that the screw will slip through it rather than engage. A screw-holding screwdriver is of assistance, but they are fragile and liable to go wrong. The use of screw-holding forceps and a plain screw-driver is often more satisfying. Drilling holes is much easier and better controlled with a motor drill. One driven by compressed air is much more satisfactory than an electrical one, as it is lighter, more powerful, and produces no sparks, and sterilization is on the whole much easier.

The Open Reduction of Fractures

Every orthopædic surgeon has sought the perfect method of internal fixation of bone. The wire, the band, the plate and screws,

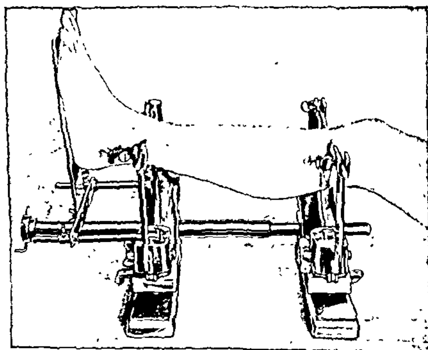


FIG 59. The lower limb, ready for distraction, lying on a mechanical distractor. (*London Splint Co.*)

have been followed by the intramedullary nail, a sign that none of the earlier methods has been perfect. The infinitely variable curves of human bone make the application of any rigid linear appliance imperfect. Some of the difficulties can be overcome by flattening the surface of the bone before the application of the plate, but this though easier with modern instruments, takes time and trouble. Each method of fixation has advantages for fractures of particular bones and of particular types. It is the correct choice of the method appropriate to a particular fracture which is important, always remembering that each method introduces difficulties of its own, and that familiarity with them is half the battle won.

Exposure of a few fractures will soon show that the irregularity of many fractures is such that no surgeon could hope to interlock the ends blindly, even given all the control available by skeletal traction. Recognition of the defects of skeletal traction has led to the use of beaded wires to provide lateral pressure on fractured bone ends, but this is open to other objections. The interposition of soft parts is often another immediate obstruction. Further the use of skeletal traction in itself has disadvantages. This is particularly so if traction is persisted in over any length of time. Stiffness of joints through which force is employed is an inevitable sequel, only varying in degree. Traction is not fixation, but a balance of forces, which exert a continual opposition to each other, varying with every movement of the patient. Fixed distraction is equally undesirable in many fractures leading to non-union and soft tissue adhesions The movements of tissues around pins and wires leads to infection of the pin tracks, so that early mobilisation of limbs fixed by these methods cannot be safely carried out. If the fractures can be fixed internally no track is left open to the skin and this objection is overcome.

The advantages of operative reduction may be stated as follows :—

1. Early, complete, and perfect reduction of the fracture with resultant benefits :

(*a*) Immediate. Avoidance of further soft tissue damage from pressure or manipulation ;

(*b*) Intermediate. Possibilities of earlier mobilisation due to greater early rigidity of the limb. With this is bound up the patient's confidence in the limb which he once again feels is solid ;

(*c*) Late. Absence of secondary effects on the joints at either end of the bone due to abnormal strains from mal-alignment.

2. The evacuation of part of the hæmatoma, with a decrease in the adhesions formed among the tissues. This is counterbalanced to a slight extent by a delay of approximately a fortnight in the establishment of clinical union.

3. The immediate comfort of the patient who finds that the one operation, apart from the removal of the stitches, is the only uncomfortable procedure to which he must be subjected.

It should be scarcely necessary to add that the operative fixation of fractures plays almost no part in the treatment of fractures during the growing period, when bones automatically realign themselves.

The disadvantages of operative reduction. The method can only be carried out by the experienced, working under good

conditions, and this limits the general usefulness of the method. The method itself introduces new complications and difficulties :—

1. *Sepsis.* That this is slightly increased by the method cannot be denied. In the most skilled hands an odd case will become infected. Whether this can be regarded as a complete contra-indication to the method is a personal decision. Such sepsis as occurs in carefully selected cases is usually of the subacute type and has no serious consequences. It may delay union and result in excessive new bone formation, and rarely produces sequestration. Its occurrence is undoubtedly related to the conditions under which the method is carried out and the skill of the surgeon. The amount of metal used in fixation is also of importance, sepsis being more common with large plates than with single screws. With a single screw secondary infection produces little further damage, but with a plate the removal of the whole appliance may become necessary.

The most common cause of infection is inadequate hæmostasis which alone, or by interfering with the blood supply of a portion of skin, produces infection of the wound. Excessive tension in suturing a wound is also a common cause of trouble.

The use of plates in open compound fractures is a difficult problem which may add to the risk of sepsis by introducing a foreign body. This will be discussed more fully in Chapter IX.

2. *Sinus formation.* This was much more common in the days when electrolytic metals which corroded were used. To-day it is more commonly the result of subacute infection. Where the condition is due to a foreign body reaction there is little tendency for infection to pass along the track and a watery serous discharge may persist for weeks. The majority of cases heal of their own accord in time. In a limited number of cases removal of the metal will be necessary.

3 *Non-union.* Like infection, which may be responsible for the condition, this is most commonly the result of faulty technique. A classical example is the separation of the surfaces of a transverse fracture by a plate which has been screwed in position holding the bone slightly apart. A secondary factor is the deleterious effect on callus formation exerted by some plates. This is due to :—

(*a*) Subacute infection around the plate, not sufficiently acute to affect the temperature chart, but indicated by radiological signs of rarefaction at the fracture line.

(*b*) Electrolytic effects of the metal. Currents of action develop between the metal and the surrounding cells. This is prevented by the use of a non-electrolytic material such as vitallium, or stainless steel.

(*c*) The size of the plates. Apart from increased electrolysis,

there is a greater intolerance displayed by the tissues the larger the foreign body present. This is independent of the material used, and encourages one to reduce the amount of material inserted to the smallest possible proportions.

4. *Technical difficulties.* Skin damage in the vicinity may prevent operation. It is desirable in the case of an abrasion to operate at once, rather than to wait till the abrasion has healed, as delay is undesirable, and infection unlikely to occur if immediate operation is carried out. The line of incision must of course be clear of all abrasions, though if these are very small they may be cut across.

5. *Rate of union.* If a small amount of metal is inserted no effect on the rate of union can be noticed. The strength of union, however, depends on the area of callus formed as well as the rigidity of the callus present. The area of callus formed is reduced when the fresh hæmatoma is evacuated by early operation. Clinical union is thus delayed. In the case of the tibia the delay amounts to a fortnight.

General Aspects of Internal Fixation

The degree of internal fixation and the degree to which it is supplemented by external fixation are capable of much variation. The limb may be so fixed by plates as to require no external support, or it may be so lightly fixed as to demand rigid external support. Each method has its advantages and disadvantages and must be adapted to the individual case.

COMPLETE INTERNAL FIXATION. The advantages offered by this method are the simplicity of the dressings and the opportunity given for early use of the limb for non-weight bearing and weight bearing exercises. The disadvantage is the bulk of metal which must be inserted and the consequent complications.

LIGHT INTERNAL FIXATION AND EXTERNAL SUPPORT. This utilises the simplest degree of internal fixation with a reduction in operative time and exposure. The external fixation necessary restricts the early use of the joints, but these never become as stiff as joints which have been under continuous traction. If the operation has only controlled the shortening, angulation may be controlled by wedging the plaster Early weight bearing in a fresh plaster is dependent on the type of fracture present and the degree of fixation obtained. Thus a spiral fracture fixed with two screws may show the rigidity of a transverse fracture fixed by a plate. Active use of the upper limb can always be encouraged and the lightest of external supports be employed.

INTERMEDIATE METHODS. This is an endeavour to combine the advantages of both methods. Light internal fixation is used and supplemented by external fixation for a fortnight. This is removed

and the stitches taken out and a plaster back slab substituted. This is removed daily for non-weight bearing exercises to knee and ankle. Activity on crutches is permitted in the case of the lower limb. At the end of six weeks the principal advantages to be gained from early movement of the limb have been established, and fixation of the knee and ankle, or any other joint concerned, will not be followed by serious stiffness. A weight bearing plaster may thus be applied and the patient encouraged to get about ; stiffness is thus avoided, but not at the cost of long periods of inactive recumbency.

Fractures in which Operative Reduction may be Indicated

A more detailed consideration of this subject will be found in the chapters concerning each special bone, but a few general remarks and an outline of the suitable fractures seem appropriate here. Generally speaking, the fractures which involve the surfaces of joints, particularly those of the lower extremity, require the most perfect reduction if the later development of traumatic arthritis is to be obviated. Such fractures often require open operative reduction. Fractures of bones which have a complex movement due to the presence of joints at either end of the bone, such as the radius, require perfect reduction for perfect function. The nearer a fracture is to a joint the more strain on the joint mal-union will impose and the greater need for perfect reduction. The bones of the upper limb, if mal-aligned, are subject to the strains of abnormal muscular contractions and incongruous joint surfaces. These are often trivial and, as a consequence, the alignment of such a bone as the humerus need not be perfect for sound function. In the leg the line of transmission of the body-weight through the limb balances the pressures on either side of the joints and any deviation from the normal will be repaid by the development of a subsequent traumatic arthritis from the uneven distribution of the strains and stresses around the joint. Mal-union in the leg is therefore serious in its consequences and must be avoided. Bearing these points in mind it will be seen that open operative reduction and fixation of fractures of the following bones is indicated if there is more than minimal displacement.

1. Fractures of the lower end of the humerus and around the elbow (Figs. 295, 306)
2. Fractures of the radius (Fig. 335).
3. Fractures of both bones of the forearm (Figs. 390, 405).
4. Fractures of the posterior margin of the acetabulum, making the hip unstable.
5. Fractures of the upper third of the femur (Figs. 507, 523).
6. Fractures of the femoral shaft (Fig. 548).
7. Fractures of both bones of the leg (Fig. 604).

there is a greater intolerance displayed by the tissues the larger the foreign body present. This is independent of the material used, and encourages one to reduce the amount of material inserted to the smallest possible proportions.

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Complete internal fixation. The advantages offered by this method are the simplicity of the dressings and the opportunity given for early use of the limb for non-weight bearing and weight bearing exercises. The disadvantage is the bulk of metal which must be inserted and the consequent complications.

Light internal fixation and external support. This utilises the simplest degree of internal fixation with a reduction in operative time and exposure. The external fixation necessary restricts the early use of the joints, but these never become as stiff as joints which have been under continuous traction. If the operation has only controlled the shortening, angulation may be controlled by wedging the plaster. Early weight bearing in a fresh plaster is dependent on the type of fracture present and the degree of fixation obtained. Thus a spiral fracture fixed with two screws may show the rigidity of a transverse fracture fixed by a plate. Active use of the upper limb can always be encouraged and the lightest of external supports be employed.

Intermediate methods. This is an endeavour to combine the advantages of both methods. Light internal fixation is used and supplemented by external fixation for a fortnight. This is removed

The use of a tourniquet is convenient. In the arm an Esmarch's bandage and a manometer are used, in the leg two Esmarch bandages are applied. These are put on over a sterile towel in which the leg is wrapped at the end of the skin preparation.

The skin is incised in the appropriate position, or the incision is designed to incorporate the excised edges of a wound if this is convenient. Care is taken to see that the vitality of the skin is not impaired by the lines of the incisions. The incision, if possible, does not cross or communicate directly with the fracture site. Curved flaps are thus usual or long incisions to one side which permit approach by adequate retraction. Towels are then sewn or clipped very accurately to the skin edges so that all contact with external skin is excluded.

With fresh instruments the tissues are dissected and the bone ends exposed. Periosteal stripping is confined to the minimum. The bone ends are then grasped in Lane's forceps and accurate alignment of the limb restored and the bone ends interlocked. A decision as to the appropriate method of fixation of the fracture will now have been arrived at. If transverse a plate may be needed. If oblique or helical, single or double-screw fixation may be satisfactory. The insertion of the screws is much facilitated by the use of a mechanical drill, either electric or pneumatic. In general, the type and position of the fracture will determine the position of the fixing agent, but where possible the subcutaneous surface of a bone should be avoided. Screws should always obtain a grip on the cortex of the bone on the opposite side, and to avoid splitting the bone they should not be put in line.

The soft tissues may be closed over the bone with a few interrupted sutures. The skin is carefully and accurately closed by interrupted skin stitches as described on p. 83. Hæmostasis is important and if there is any fear of hæmorrhage, either the tourniquet must be relaxed and the hæmorrhage controlled or a small drain must be put in for the first twenty-four hours. The limb is then enclosed in a firm dressing of cotton wool evenly bandaged on, and the whole encased in plaster. If the internal fixation provides sufficient stability the plaster is omitted and the leg supported on a cradle splint such as a Thomas splint for the first few days.

Removal of fixing agents. This is not always necessary and is dependent on several factors.

1. *Infection*. Usually subacute, it does not necessarily demand immediate removal with resultant loss or control of the fracture, but may be postponed till there is no lateral instability. In the rare acute cases a decompression of the wound is necessary to provide adequate drainage. Later on the foreign bodies may be removed.

8. Fractures of the tibia alone.

9. Fractures with displacement at the ankle joint (Figs. 650, 667).

Supporting these assertions is the fact that these fractures are those which give the least satisfactory results when treated by ordinary measures.

Selection of suitable cases. The complication to avoid at all costs is sepsis, and for this reason any infection of the skin in the vicinity, or any serious infective process elsewhere, is a contra-indication to operation. Any risk of failure of wound healing from skin damage must be carefully watched. For these reasons grossly compound fractures are usually unsuitable for primary fixation. Indirect compound fractures should heal by primary union and excision of the wound may well be combined with fixation (p. 118). Simple fractures of the types indicated previously, where a good result cannot be obtained by other methods, should be fixed. There are two periods at which this fixation may be carried out :—

1. *Immediately.* This has many advantages. Definitive treatment is given at once, and the sooner this is carried out the better. The opportunity once lost may never return. The patient is relieved of his discomfort and apart from the removal of stitches and replaster should have a steady progress to recovery ahead of him. The sharp definition of the fracture ends makes accurate interlocking easy. Evacuation of the hæmatoma reduces the risks of pressure on the skin and skin loss. If there is an abrasion immediate operation may be needed, as infection of the abrasion may prevent later operation.

2 *Delayed.* Between the fourth and the fourteenth day. This gives time for the hæmatoma and local swelling to subside a little. Adequate skin preparation may be carried out in the ward, but as some form of fixation of the fracture has probably been necessary, skin preparation in the theatre is often best. Delay may be imposed by the presence of other injuries, the general condition of the patient, or the absence of suitable facilities for operation.

General operative technique. Open operative reduction is only the method of choice where the facilities for operation approach the ideal. It should be carried out with scrupulous care and "no touch" technique. A general outline of the steps necessary will be given here and are applicable to all fractures.

It will be found convenient in early cases to combine the preparation of the skin with the operation and utilise the one anæsthetic. Preparation in the ward is painful, difficult and apt to be incomplete. In the presence of a gently continuing hæmorrhage it becomes almost impossible. The details of the skin toilet are given on p. 80, where wound excision is discussed. Shaving of the skin is unnecessary

Experience with the nail suggests that is a useful addition to the surgical armoury for certain fractures, notably the transverse fractures of the shaft of the femur, with deformity. The difficult fracture below the lesser trochanter, with cocking up of the short proximal fragment, is easily controlled. The nearer the fracture to the knee, the less suitable the method. Fractures of the tibia may also be readily dealt with, but these are satisfactorily controlled by the methods already available. For the upper extremity the method is a little clumsy. Closed introduction is best, but where closed reduction can be achieved further treatment is often unnecessary. In open reductions the advantage of a smaller wound over the fracture is offset to a slight extent by the additional incision for introduction of the nail.

Combined Internal-External Fixation Methods

The most important of these is the crossed-pin technique (anatomic splint of Roger Anderson) for the long bones, but more profitably applied by our dental colleagues to fractures of the mandible. Pins are inserted in the bones on either side of the fracture at a suitable distance, and at such an angle to one another that they control the movements of the bone completely. By fixing the pins rigidly to an external support complete mechanical control of the fracture may be obtained and it may be aligned and held in alignment. If the apparatus is sufficiently rigid, weight bearing through the appliance is possible. While dramatic in its immediate results there are several drawbacks to the method. It needs considerable experience to apply, it is not always painless when applied due to slight movement being permitted, but its chief disadvantage is the liability to infection of the pins. This is present with any pin, but is reduced in amount by using as fine a pin or wire as possible (hence the advantage of Kirschner wires over Steinmann's pins), and by having little or no movement of the tissues relative to the pin. The early movements made possible by the apparatus thus sow its seeds of

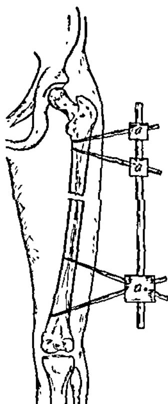


FIG. 60. Anatomic splint. Fixation of the fracture by mechanical clamping to an external bar. Alternative methods of angling the pins to obtain rigidity are shown. (Roger Anderson splint.)

2. *Atrophic non-union.* Following the insertion of large amounts of metal this may occur, and is characterised by a complete lack of new bone formation. Removal of the plates and external support is often followed by satisfactory osteogenesis. Freshening of the fractured ends of the bone may be carried out at the same time. Rarely a bone graft may be necessary.

3. *Palpable metal.* A screw head which is subcutaneous may become tender.

4. *Formation of sinuses.* These often close in the course of time without removal of the metal if they are not due to acute infection (see p. 105).

5. *Unsatisfactory position* or excessive length of screw. This may not be realised till later radiographs are taken. The screws should be left in till union is established and then removed.

KÜNTSCHER'S INTRAMEDULLARY NAIL. The use of a larger diameter intramedullary nail is a logical extension of the intramedullary Kirschner wire, and was first employed by Küntscher in 1941 (see Fig. 58). Its introduction to German surgeons was at first unfavourable, and there are still sharp divisions on its uses and value The nail, modified by various surgeons, consists of a metallic rod of varying length, triangular or diamond-shaped, or even circular on section. Some nails are slightly curved at either end to facilitate their introduction. The nail is introduced through the sites of easy approach to the marrow, such as the radial styloid, the greater tuberosity of the humerus, the great trochanter, and the tibial tuberosity.

There are two methods of using the nail, either reduction can be accomplished manually, and with or without the assistance of radiography the nail can be slid across the fracture site, or open reduction of the fracture can be carried out, and the nail slid across the fracture under direct vision ; this entailing a separate incision for its introduction. For its effective use a good selection of nails is necessary varying in both length and diameter, as it is essential that the nail should grip the medullary cavity without jamming. A nail one millimetre smaller than the diameter of the medullary cavity is chosen. Skeletal traction may be used to reduce the fracture, and some surgeons prefer to use screening. In the tibia and the femur a guide may be used to facilitate the introduction of the nail. Accurate reduction of the fracture, is the primary basis of easy and successful nailing. External support of some type is employed in most cases. There is a slight risk of fat embolism in elderly people. Technical difficulties may arise from fracture of the nail, bending of the nail, penetration of the cortex, and distraction of the fragments. The strength of union is difficult to gauge with the nail in position

definitely promise a good anatomical result, should be accepted as the method of choice. For this reason mobilisation and massage by themselves have not been found to secure a high percentage of good results. They are, however, valuable supplementary methods of treatment.

"Similarly, of operative methods, those which secure exposition and absolute fixation of the fragments yield better results than methods which fall short of this, imperfect fixation of the fragments by wire or other suture has been found to be an unsatisfactory procedure in the treatment of fractures of the long bones, with the exception of the olecranon process of the ulna.

"(9) Operative treatment should not be regarded as a method to be employed in consequence of the failure of non-operative measures, as the results of secondary operations compare very unfavourably with those of immediate operations.

"In order to secure the most satisfactory results from operative treatment, it should be resorted to as soon after the accident as practicable.

"(10) It is necessary to insist that the operative treatment of fractures requires special skill and experience, and such facilities and surroundings as will ensure asepsis. It is therefore, not a method to be undertaken except by those who have constant practice and experience in such surgical procedures.

"(11) A considerable proportion of the failures of operative treatment are due to infection of the wound, a possibility which may occur even with the best technique.

"(12) The mortality directly due to the operative treatment of simple fractures of the long bones has been found to be so small that it cannot be urged as a sufficient reason against operative treatment.

"(13) For surgeons and practitioners who are unable to avail themselves of the operative method, the non-operative procedures are likely to remain for some time yet the more safe and serviceable."

Instruments Used in the Operative Treatment of Fractures

A. Cleaning up Trolley.

1. Bowl of ether soap.
2. Bowl of sterile water.
3. Bowl of iodine or spirit.
4. Dry gauze swabs.
5. Scissors.
6. Dissecting forceps.
7. Sterile towels.
8. Esmarch's bandages. (2).

B. Operating Set. Plating of fractures, Screw Fixation, or Grafts.

1. Scalpels (2).
2. Dissecting forceps, toothed (2).
3. Dissecting forceps, untoothed (2)
4. Blunt dissector, Macewan's.
5. Spoon, Volkman's
6. Retractors, single hook.
7. Retractors, double hook.
8. Retractors, Langenbeck's.
9. Levers, bone, Lane's (2).
10. Periosteal elevator, Faraboeuf's.
11. Periosteal elevator, Macewan's.
12. Scissors, Mayo's curved, Straight (2).
13. Bone holding forceps, Lane's, serrated (2).

failure. In the jaw, where there is relatively little movement of soft parts compared to bone and delicate pins can be used, the method is effective and useful.

The use of a pin which screws into the bone and leaves a handle extending through the skin for incorporation in plaster may be helpful in fractures of the radius.

Intramedullary Kirschner wires. This method may be of value in fractures of the forearm, as it is comparatively simple to introduce it into the ulna. Its application to the radius is less satisfactory. In the ulna the fracture is exposed and the Kirschner wire passed down the shaft of the bone towards the olecranon. It is drilled through this till it protrudes behind and is then withdrawn into the end of the proximal fragment. The fracture is then aligned and the Kirschner wire pushed across into the distal fragment. In the radius a Kirschner wire may be introduced into the radial styloid and down the shaft but it is technically difficult. The method has been generally replaced by the use of Küntscher nails or rush pins.

B.M.A. Report on the Operative Treatment of Fractures

In 1910, as a result of the acute controversy around the subject of the operative fixation of fractures, a committee of the B.M.A. was appointed to report on the subject. The high standard of this committee needs only the names of Victor Horsley, Wilfred Trotter and Rutherford Morrison to be mentioned to testify it. It is appropriate here that their findings should be reported as the passage of thirty years has not altered their validity in any degree, and they balance nicely the position of the immediate operative reduction of fractures.

"(1) The statistics relative to the non-operative treatment of fractures of the shafts of the long bones in children (under the age of fifteen years), with the exception of fractures of both bones of the forearm, show as a rule, a high percentage of good results. These are unlikely to be improved upon materially by any other method of treatment. Operative results in children expressed in percentages, are approximately the same as non-operative.

"(2) It is possible either by non-operative or by operative treatment to obtain a high percentage of good results in children.

"(3) In comparison with the non-operative results in children, the aggregate results of non-operative treatment in those past childhood (*i.e.* over the age of fifteen years), are not satisfactory.

"(4) From the analysis of the age groups it is clear that there is a progressive depreciation of the functional result of non-operative treatment as age advances, that is to say, the older the patient the worse the result.

"(5) In cases treated by immediate operation, the deleterious influence of age upon the functional result is less marked.

"(6) In nearly all age groups, operative cases show a higher percentage of good results than non-operative cases.

"(7) Although the functional result may be good with an indifferent anatomical result, the most certain way to obtain a good functional result is to secure a good anatomical result.

"(8) No method, whether non-operative or operative, which does not

CHAPTER IX

THE TREATMENT OF COMPOUND FRACTURES

Historical. The compound fracture has been the occasional result of accident and the inevitable result of war since gunpowder was invented. The peculiar severity of the gunshot wound led to the suspicion that the bullet was poisoned, and when this was proved incorrect, to a still firmer grip on the public mind, of the superstitions with which the formation of pus, mortification and gangrene were surrounded. The role of Ambroise Paré (1510–90), who started the long work of clearing the dead weight of mediæval superstition from the shoulders of the experimentalist, is interesting reading in his own words. The process is nearly complete. It is interesting however to note the general reluctance of the public to leave a wound to nature. Everyone has their ointment or lotion guaranteed to heal better than their neighbours. The popularity of the new chemotherapeutic agents is as much due to the fact that a magic remedy is available as to their proved clinical value.

The great strides in the treatment of compound fractures are not due to the sudden discovery of new principles. Excision of wounds was practised centuries ago, and was well described by Charles Bell 100 years ago, plaster is still more antiquated. The developments are due to a slow discovery that the powers of nature, when given ideal conditions to work under, are enormous, and can be relied upon as a defence mechanism. This attitude is the result of the work of physiologist, surgeon and bacteriologist, who have produced a continuous picture of wound pathology. Outstanding names in this story are few or many according to the wish of the selector. It is perhaps easier to fix a few dates marking progress than to attempt any analysis of credit.

1744–95. P. J. Desault. Surgeon to the Hotel Dieu in Paris at the time of the French Revolution. He thus gained considerable experience in trauma and was responsible for advances in the treatment of fractures and wounds. His most important contribution was his insistence on the debridement of wounds, which though lacking a scientific basis till the work of Pasteur proved so successful that it was widely adopted.

1766–1842. D. J. Larrey. He gained his experience as a pupil of Desault, and as surgeon to Napoleon, who left 100,000 francs to "Larrey, the most virtuous man I have ever known." A humanitarian, beloved by his men, he sought to bring the wounded treatment as early as possible, and to this end developed the use of ambulances, taking the hospital to the wounded. So efficient was his organisation, that in the Egyptian Campaign he was able to boast that no patient remained more than fifteen minutes without attention. He thus carried on the tradition of excision, and appreciated the value of early treatment. In addition, he made observations on the value of maggots in wounds, the onset of gas gangrene, and *trench foot*.

1822–95. L. Pasteur. The work of Pasteur and his followers has provided the rational basis on which the pathology and treatment of wounds is based. The son of a soldier in Napoleon's army, now settled as a tanner in the Jura, Pasteur started life in a humble fashion. The trail of his researches, starting with crystallography and progressing through fermentation, spon-

14. Bone holding forceps, Lane's, toothed (2).
15. Plate holding forceps.
16. Screw holding forceps.
17. Plates.
18. Screws
19. Screwdriver.
20. Drill, pneumatic, electric, or hand. (For grafting must be motor-driven).
21. Bits. One thirty-second to one-sixty-fourth smaller than screws.
22. Circular saws on spindles. To fit drill chuck, of which Jacobs is best type.
23. Counter-sink bit.
24. Bone-nibbling forceps.
25. Gouges, bone, ¼ and ½ inch, deeply curved.
26. Chisel, ¼ and ½ inch wide.
27. Hammer.
28. Sequestrum forceps.
29. Needles, round bodied and cutting edge.
30. Needle-holder.
31. Suture material ; thread, catgut and stainless steel wire.
32. Spencer Wells' forceps (6).
33. Allis' forceps (6)
34. Moynihan's towel clips (2).

FURTHER READING

LANE, W. ARBUTHNOT. "The Operative Treatment of Fractures." London, 1914, 2nd Ed. The Medical Publishing Company.

INGELRANS, P. "Biologie de l'ostéosynthèse Metallique." L'écho Médical du Nord. 1944, 15, 185.

CHARNLEY, J. Fracture Treatment. "Modern Trends in Orthopædics." Butterworth, London, 1950, Chap. 2, 22.

NADEN, J. R. "External Skeletal Fixation in the Treatment of Fractures of the Tibia," *J. Bone and Joint Surg.*, 1949, 31A, 586.

R. WATSON JONES *et al.* "Medullary Nailing of Fractures after Fifty Years," *J. Bone and Joint Surg.*, 1950, 32B, 694.

EVANS, F. G., *et al.* "The Role of Tensile Stress in the Mechanism of Femoral Fractures," *J. Bone and Joint Surg.*, 1951, 33A, 485.

BOHLER, L. and J. "Kuntscher's Medullary Nailing," *J. Bone and Joint Surg.*, 1949, 31A, 295.

VENABLE, C. S., and STUCK, W. G. "Internal Fixation of Fractures." Blackwell, Oxford, 1947.

BOHLER, L. "Medullary Nailing of Kuntscher," Eng. Ed. Balliere, Tindall and Cox, London, 1948.

simple and infallible road to success but demanded qualities of experience, and judgment in the surgeon of the highest order.

1939–45. SECOND WORLD WAR. In spite of the experiences of the past, and the recent lessons of the Spanish War, much remained to be re-learned and re-discovered. Excision was not firmly established. Abortive methods to apply the "closed plaster" technique without adequate debridement were made with disastrous results. Slowly the experience gained, coupled with a better organisation for the diffusion of knowledge, led to the complete evaluation of methods and improvements in technique. Coupled with the use of transfusion, intravenous salines, and the new chemotherapeutic agents, a survival rate unexampled in previous wars was achieved.

1940. SIR HOWARD FLOREY decided to investigate afresh the properties of the available antibiotics. Unknown Penicillin was lying to hand, having been discovered by Sir Alexander Fleming in 1928, following the accidental contamination of a petri dish containing staphlococci with the mould. A re-examination of its promising properties was undertaken, which established its enormous clinical value. With Britain fully extended, it was impossible to set aside the necessary machinery and manpower for its preparation. Its first commercial manufacture was thus begun in America. Neither it nor the sulphonamides affect the standard principles of wound treatment. The best they do, and it is much, is to modify the method chiefly with regard to the time factor, and the risks of its application.

The principles of treatment of compound fractures are exactly similar to those outlined for the treatment of wounds of the soft tissues. The observation of these principles and the achievement of a satisfactory result is rendered much more difficult as the result of the complications introduced by the wound communicating with the bone. The mere perforation of the skin by a spicule of bone (indirect compound fracture) may add little to the difficulties encountered, and may sometimes be treated as a closed fracture. At the other extreme the gross fragmentation of the bone, the crushing of soft tissues, and the loss of skin cover may make amputation the wisest course to follow.

The additional complications encountered in an open fracture may be one or all of those following.

1. *Increased shock*, with greater depth of wound, and increased soft tissue damage, resulting in blood loss, and subsequent loss of tissue fluids into the part.

2. *Increased liability to infection.* This is very variable and dependant in the first instance on the type of wound. Injuries in which skin and clothing are driven into the deeper aspects of the wound have a bad reputation. Crushing of soft tissue, provides a nutrient medium for organisms, and it may not be possible to excise it all. Loss of skin cover of the wound inevitably makes infection more likely.

3. *The loss of rigidity of the limb.* This increases the risk of infection by permitting movement of the soft tissue planes and so

taneous generation, diseases of wine and beer, diseases of silkworms, to human disease, is one of the most moving in medical history. Rarely has such affection for humanity, courage and devotion been combined with such intellectual power and achievement. Affected by a stroke in the last years of his life, Pasteur died the most honoured "layman" in the profession.

1843–1910. KOCH. The work of Pasteur was ably seconded by Robert Koch, who in 1876 was able to describe the complete life history of the anthrax bacillus. In 1878, his paper on infectious diseases of wounds appeared, in which he described the clinical and bacteriological findings in infections with six different types of micro-organisms.

1827–1912. J. LISTER. Following Pasteur's researches, Lister on August 12th, 1865, carried out the first successful operation on a compound fracture by his "antiseptic" method. This was dependent entirely on the use of carbolic acid. Lister paid great attention to the type of dressing used (double cyanide gauze is a relic of his work), and the arguments which grew around them, and his priority in the use of carbolic, would have embittered a man of less nobility of character.

1914–18. FIRST WORLD WAR. This was still the era of antisepsis. Wound excision had been lost sight of, and the surgical tragedies of the first six months of the war necessitated a revision of technique. Excision was re-discovered, and its early success led to the attempt of universal primary suture. This produced a second crop of tragedies, and was responsible for the development of the Carrel-Dakin methods, and other less successful ideas such as the bismuth-iodine paraffin-paste, known as Bipp. Robert Jones, by insisting on the immediate immobilisation of the limb on a Thomas' splint, re-emphasised the principle of early treatment and rest. Lorenz Bohler, as the result of his experiences during the war, developed the principle of excision, complete rest, and the windowing of the plaster over the wound. Thus wounds lay in a bath of pus, but this was not disturbed more than necessary. He thus approached closely to the "closed plaster" method. Böhlers' chief contribution to the surgery of fractures is, however, regarded as the development of mechanical methods of reduction and the organisation and segregation of fracture cases. Bohler first proved that this had an economic as well as a therapeutic value and so laid the foundation stone of all accident hospitals.

1929. WINNETT ORR, as a result of his experience with osteomyelitis which he successfully treated by pack and immobilisation in plaster, applied the same principles to the treatment of infected compound fractures with great success. The infrequency of dressing, the comfort of the patient, and the satisfactory progress were impressive. It was not long before it was used as an immediate line of treatment for compound fractures with impressive results. In England, after Orr's visit in 1930, the method made little progress, probably because of the difficulty of evaluating any method without individual experience of large numbers of cases.

1933. First reports of the value of the sulphonamides began to appear in Germany. In 1935 its value was experimentally assessed in England against puerperal sepsis, and since then there has been a steady increase in numbers of the sulphonamide family synthesised and their use.

1936–39. The Spanish War provided the first large field for the use of new methods. J. TRUETA, who had been working with this technique in civil surgery with good results, slowly popularised the method which became known as the "Closed plaster method." His efforts in this country at the outbreak of the present war were largely responsible for the dissemination of the fundamental principles underlying the method, and the insistence that it was no

pletely. Owing to the difficulties with cross leg flaps sepsis is apt to penetrate under the flap to the fracture site.

5. *Complications due to avascularity.* *a.* Of the skin. The under surface of the skin may be scraped bare of fat by the sharp bone end and its liability to gangrene not recognised. Early inspection of contused and run-over wound is therefore wise. Such areas should be excised and covered by the appropriate plastic procedure. *b.* Of the bone. It is becoming more generally recognised that the cause of many unexplained cases of delayed or ununited fractures is the stripping of the end of the bone of its soft tissues after wide displacement of the fracture. This results in a



FIG. 62. After excision and wound toilet the area is covered with large Thiersch grafts. This is an emergency cover till full thickness skin can be transferred.

partial avascular necrosis and delayed or suppressed new bone formation. It is obviously unwise to add to the risk of this complication by stripping the ends of the bones, or detaching small fragments of bone from their blood supply by extensive operations. The minimum exposure for the work to be done should be used.

6. *Crushing of soft tissues* and deep damage with resultant impairment of function due to adhesions. Adhesions are greatly increased by any subsequent infection.

7. There is inevitably a greater liability of damage to nerves, arteries, tendons and other important soft tissue structures.

Wound Excision in Compound Fractures

The principles remain the same as those described for uncomplicated soft tissue wounds. A greater variety of soft tissue damage is, however, likely to be met with and the correct treatment of each tissue must be described in more detail.

Skin and subcutaneous tissues. Excision of the contaminated

exposes new tissue to infection. Fixation of the fracture is therefore essential to assist in the development of a barrier against infection, and the healing of the wound. The best way to achieve rigidity of the limb depends on many factors. Generally the use of internal fixation should be avoided, as it adds a foreign body to the wound and its insertion demands wider stripping of tissues and increases the chances of rendering some portion of the fracture avascular. Each fracture must be treated on its merits. To an indirect compound fracture it adds little risk, and as these are usually oblique or spiral they may be safely fixed with two screws when the wound is dealt with. In other cases when there has been large areas of skin



FIG. 61. Area of skin loss over a compound fracture of the elbow due to a "run over" injury.

loss, the fixation of the fracture enables plastic procedures to be carried out more easily, and so may become advisable.

4 *Inability to close the wound.* This may be due to gross swelling of the limb If there has been no skin loss it is usually a relatively simple matter to swing a flap or strip of skin over the bone so as to close off the fracture, and to leave a raw area over uninjured tissues which may be Thiersch grafted.

More commonly the difficulty is due to actual skin loss, *e g*, in a run-over accident, where a wide band of skin, and usually more than anticipated, is likely to become gangrenous. Here some knowledge of plastic procedures is essential. The object is to seal off the fracture by attaching living skin to living tissues over it. Thus in the leg, flaps of skin may be swung over the tibia and attached to the anterior tibial muscles. The resulting defects are made good by subsequent Thiersch grafting. Occasionally there is an opportunity to use a flap of skin from another site These are easier in the upper limb where the abdomen or chest is a good source of skin, and there is enough skin to close off the fracture site com-

are tied if necessary. Large vessels must obviously be tied, and this may be done at once (see Injuries to Vessels, p. 53).

Bone. Only the soiled surfaces are removed by the use of the nibbling forceps or the chisel and hammer ; this normally applies



Fig. 63. Gross skin loss over a compound fracture of the tibia. By making a long postero-medial incision a wide strip of skin has been displaced laterally and sewn to the tibialis anterior. The gap on the other side of the leg, which cannot be seen, was covered with a Thiersch graft, and after excision of the dead skin over the tibialis anterior this was closed with a Thiersch graft.

to the soiled sharp ends of bone only. Small fragments of bone are removed if they are severed from all soft tissue connection. Large fragments are always retained as there is a definite risk of non-union if a large gap is left between the bone ends. Even if completely detached they may act as bone grafts in a clean wound. In an



Fig. 64. Satisfactory healing of the grafted area and skin closing off the fracture. Internal fixation was used to stabilize the limb.

infected wound they may also lead to some new bone formation around them before being thrown off as sequestra.

In general, all non-viable tissue is removed and an attempt made without the sacrifice of living tissue to make the wound a flat and shallow one into which the gauze can be easily packed if the wound is to be left open. If it is to be sutured these considerations do not hold. There is no objection to draining a sutured wound for twenty-four to forty-eight hours, and where there is much bleeding from bone ends this is often desirable.

surfaces of these tissues down to the level of the fascia, avoiding excessive removal of skin, and leaving a regular clean edge.

Skin has a high resistance to infection, and must not be sacrificed unnecessarily. Clean cut edges may be left, bruised edges cut back to unbruised tissue. Avascular skin must be cut away till a freely bleeding edge is encountered. If this results in too great a skin loss to close the wound steps must be taken to do so by flaps or grafts One possible exception exists to this. Where no plastic surgeon can be called to assist it is permissible to stitch the skin back as a cover against infection while assistance is being sought in designing the correct procedure.

Fascia and fibrous tissue. Removal of all loose tags. Where the fascia is soiled an attempt may be made to clean it and if this fails it must be excised. One must often weigh the chance of spread of infection by removal of a fascial barrier against the chance of infection by leaving soiled tissues. More important is the barrier offered by fascial planes to efficient drainage in the wound which is left open It is often safer to divide the fascia transversely where this risk exists, so that retraction of the ends offers a wide path of escape for exudates. An essential part of excision is incision to allow free drainage and saucerisation of the wound. No fear must be felt of a wide and free opening of all tissue spaces.

Muscle. All seriously bruised muscle must be removed, and all loose portions, so that fresh living cells only remain. Living muscle bleeds when cut, and contracts when pinched.

Tendons. All loose tags are cleared up. The answer to the vexed question of tendon suture is dependent on the risk of infection of the wound The problem is a critical one in the treatment of hand injuries where special conditions prevail. Where a wound is a clean incised one, tendon suture may be carried out in suitable tendons if the cut can be conveniently extended for access Extensor tendons can always be sutured under these conditions. Flexor tendons in the hand can be sutured if they are outside the " no man's land " between the proximal crease of the fingers and the distal crease of the palm. Here both profundus and sublimis are liable to be cut and experience shows that a late tendon graft produces better results.

Larger tendons elsewhere in the body should be repaired. For all tendon repairs stainless steel wire, single or plaited, is the best material to use.

Nerves. Nerve ends are freshened and sutured together by the nerve sheath with a few fine silk sutures.

Blood vessels. These are caught early and left clamped if possible during the rest of the operation. At the end of the operation they

condition of the patient, if it occurs, though with antibiotics the reaction to infection may be markedly reduced. If in doubt inspect by removal of the plaster.

Where a drain has been inserted a window may be incompletely cut through the plaster and completed at the time the drain is removed. Plaster being porous allows wounds to dry under it satisfactorily, though it is undesirable over large raw areas.

Absolute rest of the whole part and the elevation of the limb to avoid swelling are important. To obtain this the patient is usually best in bed, with the lower limb placed on a Braun's or Thomas splint. The upper limb may be placed on a pillow or attached to a lateral bed frame as shown in Chapter XXI.

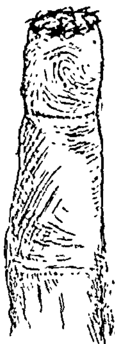


Fig. 65. Whole thickness pinch graft applied to the amputated tip of the pulp of a finger.

Sutures. The most useful material is provided by stainless steel wire which, because of its uniform strength and easy tying, enables hair-line sutures of wounds to be quickly and accurately carried out. They have the advantage of holding if only a single knot is tied when tissues are not under tension. On the face this fact may be used lightly to approximate tissues which may become infected. On the face sutures should be removed as soon as possible to avoid scarring, and as the healing of the face, hands and scalp is rapid this can usually be carried out before the fifth day. Under no circumstances should suturing be carried out under excessive tension, and on the face the tissues should be merely gently laid together. There is no objection to leaving skin sutures below a plaster for several weeks. It is usually convenient to remove the sutures at the end of the second week when the subsidence of swelling of the limb usually compels replaster.

Wounds which cannot be closed (see also p. 118). A classical if minor example of this is the use of a whole thickness pinch graft in cases of partial amputation of the terminal phalanx, where preservation of length is important. Having completed a neat guillotine amputation through the pulp, and after adequate hæmostasis a fat free pinch graft is sewn over the raw area (Fig. 65). Such grafts do remarkably well in most cases and not only save length of finger, but avoid the unpleasant consequences of infection.

In serious accidents time cannot always be spent in placing large grafts over raw areas, because the patient's condition may not

Compound fractures fall into two great groups :—

(A) THOSE WHICH CAN BE COMPLETELY CLOSED, as the skin loss is negligible. This is ideal but may not be desirable, as in the case of war wounds of any severity. Accordingly these may be divided into

1. Those in which closure and primary union is aimed at.
2. Those in which the wound is left open.

(B) THOSE WHICH CANNOT BE CLOSED DUE TO LOSS OF SKIN. This loss may be accepted and the wound left open, or the wound may be covered by a skin graft or flap, or by appropriate incision the wound over the bone may be closed, and a wound in a less important area left open.

1. Those in which the wound is covered leaving a raw area at some distance from the fracture.
2. Those in which the wound is packed and left open.

We may discuss a few important points concerning these in more detail.

Wounds with primary closure. The opportunity is provided here for the first and last time of obtaining perfect reduction under visual control, and great care should be taken to make sure that reduction is satisfactory and retention sound. It is undesirable to re-manipulate a compound fracture within fourteen days of its infliction, as infection which was localised may spread. Should a compound fracture be met with healing by primary union with the bones in mal-position, correction by gradual methods such as traction may be undertaken, but it is often safer not to disturb them until four to six weeks when they may be reset by a secondary operation.

Absolute fixation of the soft tissues and the bone is essential and is best provided by the application of plaster, or by plaster and skeletal traction The use of internal fixation in the " clean " compound fracture is not to be forgotten (p. 104). The use of traction for reduction may be necessary, but continuous traction alone plays no part in the immobilisation of a compound fracture. It does not provide sufficient lateral stability and tenses tissue planes in an undesirable manner Fixation by the incorporation of the wire or pin in the plaster is preferable to continuous traction in compound fractures

Windowing the plaster. There are certain objections to this, notably the tendency of the tissues to prolapse through the opening if there is any swelling of the limb. In wounds adequately excised with adequate hæmostasis there should be little swelling as all products can drain away Observation of the wound is unnecessary, unless there is a suspicion that the skin will necrose. This must be dealt with at once Infection will be indicated by the general

condition of the patient, if it occurs, though with antibiotics the reaction to infection may be markedly reduced. If in doubt inspect by removal of the plaster.

Where a drain has been inserted a window may be incompletely cut through the plaster and completed at the time the drain is removed. Plaster being porous allows wounds to dry under it satisfactorily, though it is undesirable over large raw areas.

Absolute rest of the whole part and the elevation of the limb to avoid swelling are important. To obtain this the patient is usually best in bed, with the lower limb placed on a Braun's or Thomas splint. The upper limb may be placed on a pillow or attached to a lateral bed frame as shown in Chapter XXI.

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In serious accidents time cannot always be spent in placing large grafts over raw areas, because the patient's condition may not

permit it. Twenty-four to forty-eight hours later this can usually be satisfactorily carried out, and the delay may give time for doubtful areas to be better judged. In small areas, particularly on the hand, immediate cover is desirable. A flap may be swung over, or the filleted skin of a lost finger used to cover a raw area. Thiersch grafts on vascular surfaces are always available as a temporary or permanent repair. Occasionally the hand may need to be covered with an abdominal flap.

Closed plaster method. In open compound fractures in which infection is to be expected, or in which the wound cannot be closed,

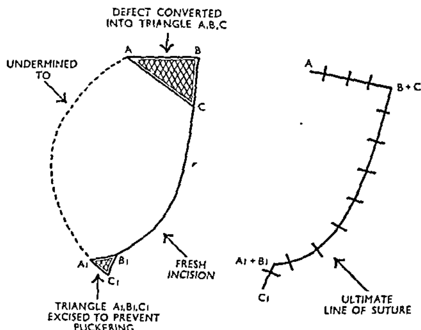


FIG. 66. Details of the advancement flap, one method of closing skin after small skin loss, which can be converted easily into an approximate triangle This is capable of many variations.

firm immobilisation and free drainage under plaster is the safest and most satisfactory method of dealing with the case. Care is taken that no pockets liable to infection are left, and, in particular, fascial barriers which tend to close so rapidly, if incised longitudinally, are incised widely in a *transverse* direction. The skin wound and that in the superficial fascia are extended widely so that when the wound is lightly packed there is no question of the wound being plugged. Dependent drainage is provided as far as possible. This is of particular importance in the thigh.

Having excised the damaged tissue, saucerised the wound and controlled the hæmorrhage, *the wound surfaces are lightly " frosted "* with a mixed powder (see p 91) and then packed lightly (" with the firmness you would hold a lady's hand on greeting her ")

to the surface level with gauze. The packing holds the surfaces of the wound widely but lightly apart. The value of impregnating the gauze with vaseline and other substances has been maintained by many observers, but in practice the profuse discharge which arises soon impregnates the material with pus and nullifies the value of most added drugs. Experiments with gauze containing penicillin, or special bacterial flora to reduce odour have yet to be completed. Of more value is the covering of the skin in the immediate vicinity of the wound with vaseline gauze which prevents it becoming waterlogged, and the seat of follicular abscesses from its enforced bath in pus. The whole limb is then placed in a lightly padded or non-padded plaster, making sure that the immobilisation of the limb is complete. In all places but the thigh this is easily accomplished. In correctly excised wounds no danger should arise from enclosing the limb in a complete plaster, as the hæmorrhage and œdema which produce dangerous pressure in the closed fracture should be reduced by the excision and have an opportunity to escape into the plaster.

The value of the gauze pack is fourfold :—

(*a*) It steadies and closes up tissue planes enabling rapid adhesions to be formed.

(*b*) It exerts an even pressure on the walls of the wound, preventing their prolapse and the pocketing of material, and the development of œdema. It also reacts in an unknown manner on the local circulation which responds much more satisfactorily under light pressure.

(*c*) It adsorbs and absorbs discharges which work their way readily to the surface without undue pressure, and aids at first in the control of capillary hæmorrhage.

(*d*) It prevents the loss of heat and moisture from the wound surface and gross soiling of the wound from external organisms.

Under these conditions the wound is rapidly lined with granulation tissue, effectively localising infection to the surface of the wound. Considerable discharge is produced and the plaster is rapidly soiled. The activity of saprophytic organisms in the pus produces an unpleasant odour which is the only objectionable feature of the method. It is most satisfactorily combated by enclosing the plaster in an air-tight bag. The material composing the bag is of little importance As a general rule, the development of a ripe odour corresponds to a full development of granulation tissue and indicates the moment for redressing the wound and reducing the amount of packing.

Organisms. Nothing is more remarkable than the variety of organisms which can be cultured from below a plaster, varying from the most innocent saprophyte to the most virulent coccus, and each

apparently interfering little with each other and less with the patient. The material available is an ideal breeding ground for organisms, and the success of the method is the organisation of the defences before heavy growth of organisms occurs, hence the value of the bacteriostatic effect of chemotherapy. Organisms commonly met with under plaster are :—

Organisms	
Staph. Albus Diphtheroids Micrococci	May be present in the early stages in a wound which will heal by primary union.
Staph Aureus *Strep. Hæmolyticus* (Pyogenes) Aerobic. *Strep. Hæmolyticus* (Pyogenes) Anaerobic. *Strep. Viridans*	Responsible for serious infections, the streptococcus in particular because of its invasive powers.
Cl. Welchii *Cl. Œdematiens* *Cl. Septique*	Present without invasion and serious effects, or together and acting symbiotically, often with the *Streptococcus hæmolyticus*, in gas gangrene.
Proteus. Vulgaris *Ps. Pyocyaneus* *Ps. Fluorescens* *Cl. Bifermentans* Enterococci	Saprophytes and contaminants appearing and disappearing from the pus.

The source of infection in most cases is soiling of the wound at the time of injury with outside organisms, or organisms from the skin of the patient. Air-borne contamination from naso-pharyngeal secretions should be guarded against by opening the wound only after it has been covered under theatre conditions. Change of dressing and of plaster should similarly be made under aseptic ritual and not in the general ward if it can be avoided, though once a well-developed granulation tissue surface is developed cross infection is as a rule of no serious significance.

Post-operative course. Nothing is more satisfactory than the post-operative course of a patient progressing normally under closed plaster treatment. His temperature may be raised for the first three days even as high as 103 degrees, but his general condition remains satisfactory, that is to say, his tongue is clean, he has a fair appetite, sleeps soundly, looks bright, and, most important, is free from pain. Persistent pain, which is more than discomfort and is obviously not due to any localised pressure of the plaster, is due to the development of some complication, either vascular obstruction,

the most urgent and serious condition, or the extension of an inflammatory process, and steps should at once be taken to find the cause.

The Complications of Closed Plaster Treatment

VASCULAR OBSTRUCTION. The development of pressure inside the plaster in cases with open wounds is not common if the wound has been correctly excised and lightly packed, as the products of hæmorrhage and infection escape under the plaster. A complete plaster on an open wound is far safer than on a closed wound, where it should not be applied within the first twenty-four hours. Œdema from crushing or infection may however produce pressure, and it is safer if the wound cannot be continuously supervised to split the first plaster in a single line throughout its length. Any appearance of congestion or œdema of the toes demands the same precaution as the circulation fails slowly and irregularly, and delay may result in some covered portion of the limb being completely deprived of its blood supply.

LYMPHANGITIS AND ADENITIS. This is due to the invasion of the tissues by streptococci and the initial temperature is often high. The wound has a bright red edge which shows a firm œdema, and streaks of erythema run up to the nearest group of lymph glands which may be enlarged and tender. Chemotherapy is commenced at once, if not already being administered. Free drainage is assured to the wound, and in the case of smaller wounds heat in the shape of foments may be applied to the wound and the glands. The condition usually settles satisfactorily, but may leave abscesses in the glands and between the superficial fascia and the skin which require to be opened.

CELLULITIS. The onset is often slower than in streptococcal infections, and is due to poor resistance to a mixed infection, assisted perhaps by pocketing and inefficient drainage. The wound is dirty, shows pale unhealthy edges and a free mucopurulent watery discharge. The tissues around the wound are tender and turgid and an area of superficial œdema frequently accompanies the tracking of underlying pus. Free drainage must be obtained by the removal of any sutures or packing and the establishment of dependent drainage. The use of a window in the plaster however undesirable must often be necessary to maintain soft tissue fixation as far as possible and yet allow inspection of the wound. Wounds which can be readily dressed and where the limb is stable may be lightly packed, covered with "tulle gras" and the whole covered by hot saline packs renewed regularly. Tracking of pus is usually due to defective drainage and demands opening of the track and light packing. The wound usually settles satisfactorily with this treatment, but the

apparently interfering little with each other and less with the patient. The material available is an ideal breeding ground for organisms, and the success of the method is the organisation of the defences before heavy growth of organisms occurs, hence the value of the bacteriostatic effect of chemotherapy. Organisms commonly met with under plaster are :—

Organisms	
Staph. Albus Diphtheroids Micrococci	May be present in the early stages in a wound which will heal by primary union.
Staph Aureus *Strep. Hæmolyticus* (Pyogenes) Aerobic. *Strep. Hæmolyticus* (Pyogenes) Anaerobic. *Strep. Viridans*	Responsible for serious infections, the streptococcus in particular because of its invasive powers.
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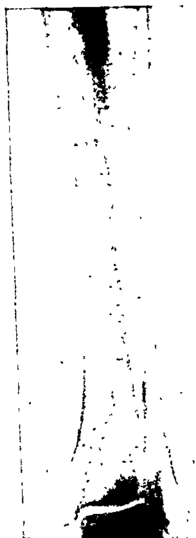


FIG 67. Compound comminuted fracture of both bones of the leg, after reduction by traction and operative excision of the wound.



FIG 68. Same case as Fig. 67. Sepsis followed. After a period of immobilisation in non-weight bearing plasters, a walking iron is fitted, and weight bearing allowed.

the general health of the skin below a plaster, and a few days may be allowed for this between changes of plaster in long-standing cases.

PLASTER DERMATITIS. All varieties of irritation may be met with below a plaster from a dry eczema to an acute desquamating dermatitis. In susceptible subjects it may be met with below a dry plaster, but is more commonly met with in the presence of an infected wound. To avoid irritation of the skin the application of vaseline gauze below

presence of an inflammation with its added complications, such as increased length of treatment, severe adhesions, vascular changes and causalgia, may in a doubtful case tip the balance in favour of amputation. In the case of most compound fractures, where an amputation at the site of election through uninfected tissues is not possible, the amputation should be through the site of fracture and open up as little fresh tissue as possible. No pockets should be left and the surface of the wound left wide open. Occasionally amputation through the knee or elbow, with minimal exposure of muscle planes, may be of value in minimising spread of infection.

Gas gangrene. This rare complication is described together with tetanus at the end of the chapter.

Later Complications of Open or Infected Fractures

Persistence of infection. This is nearly always due to the development of a complication and not to the low general resistance of the patient. It may and often is due to defective drainage. A compound fracture of the thigh never drains satisfactorily through an anterior incision, and a posterior wound for gravitational drainage must be provided. More commonly, it is the presence of sequestra, easily recognised radiologically because of their excessive density, which delay healing. Removal of dead fragments of bone by the most convenient approach through the wound is usually rapidly effective. The after-treatment of such a procedure may be similar to the closed plaster treatment in the beginning. The clinical signs of sequestra, apart from delay in healing, are the persistence of sinuses, a profuse watery sero-purulent discharge, and the presence of profuse rather œdematous and pouting granulation tissue around the wound edge. After long established infection the walls of the wound may become very fibrous and thickened and may fail to close in one cavity, producing a persistence sinus. Wide excision of the sinus and saucerising the wound will usually produce rapid healing of the wound. It is particularly in areas where there are awkward arrangements of tissue planes from the point of view of drainage, such as around the hip, that sinuses are apt to persist and may require very wide excision for their cure

Unhealthy surrounding skin Wounds are often met with in which the surrounding skin becomes the seat of multiple follicular abscesses, is œdematous and the wound edges unhealthy. Mere re-plastering results in a continuation of the condition. Such wounds often respond satisfactorily to exposure to air, which may be arranged by windowing the plaster, or the change to a skeleton form of splintage such as a Thomas splint. It must not be forgotten that exposure to air and thorough washing may be of great benefit to

The best safeguard against dermatitis is the regular washing of the skin with soap and water every time the plaster is changed. It is surprising how often this simple precaution is forgotten.

WOUND IRRIGATION. The Carrel-Dakin method of treatment, which was developed in the first war, consisted in the burial of tubes in the depths of the wound, held in place by sutures or light packing. The tubes were flushed through every few hours with a neutral or mildly antiseptic solution such as eusol. Though originating as an extension of the "antiseptic" methods then in vogue it had much success because of its adherence to the principles of immobilisation and freedom of disturbance of the wound. Only in a few cases is the removal of the discharge by this method of value, but there are possibilities in the method if the irrigating substance is bacteriostatic, as in the case of penicillin, which has given good results in old standing staphylococcal lesions. Recently a revival of the method by the use of a watertight envelope (Bunyan Stannard) has been employed, primarily for burns. Under certain circumstances, such as the combination of a burn and a fracture, it may be useful and may be used in cases of severe plaster dematitis. Combined with skeletal traction, it may clear up rapidly superficial skin infections enabling an early graft to be carried out, or minimising the delay before plaster can be employed.

EPITHELIAL LOSS. Large areas of epithelial loss may delay the healing of a compound fracture. It must never be forgotten that as soon as deep infection of bone or soft tissue is cleared up, and a satisfactory granulatíon tissue bed obtained, a skin graft will hurry up healing, and, more important, provide a better skin surface. If subsequent procedures have to be carried out on the bone healthy skin over the fracture is essential, and a pedicle graft may be necessary to make the approach satisfactory. Time should not be wasted in waiting for skin repair, but this should be encouraged by the use of Thiersch, pinch or pedicle grafts.

Modifications of method entailed by war. The object of a fracture service is the provision of the most highly skilled service available, at the earliest possible moment after injury. It is in the first few hours after the infliction of a wound that surgical treatment is decisive. No amount of after-treatment in skilled hands can alter the after-effects of preliminary disasters. Though this ideal remains the same in war, it remains more remote by reason of delays and difficulties. The lack of sufficient trained personnel makes it necessary to ensure that the methods adopted and taught to the less specialised are safe and simple and give the best results in the aggregate of cases. Necessarily this is not always ideal, but is ideal under the prevailing conditions of war.

Of paramount importance in handling casualties is evacuation, and attention is rightly concentrated on this. No treatment other than that necessary to forward a man along the chain of evacuation should be carried



Fig. 69. Union follows slowly, but a sequestrum develops, which requires removal, now that it is well demarcated



Fig. 70 Final result after removal of the sequestrum.

the plaster in "closed plaster" cases is often effective. A short period of freedom from plaster is usually the most effective remedy. In intractable conditions painting the skin with silicone ointment may be helpful, or the use of a plastic skin dressing which can be sprayed on.

should be removed if visible or palpable in the general debridement of the wound, but should not be specially sought for in tissues at a distance from the wound. Metallic fragments do not hinder union and may be incorporated in the callus (Fig. 70A). Larger metallic fragments should be removed if they are readily accessible. They should be sought for specially if :—

1. There is progressive hæmorrhage in the soft tissues around them.
2. The fragment lies in a joint.
3. The fragment is in the vicinity of a large vessel or nerve.
4. If it is excessively large.
5. If it is palpable.

Wounds from larger foreign bodies fall roughly into two main categories. Those with a clean entry and exit wound and little evidence of tissue damage. Those with a jagged entry or exit wound and obvious tissue destruction below.

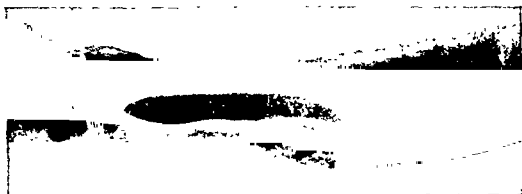


Fig 70B. Compound comminuted fracture of ulna, due to a bullet, seen lying over the radius. Note : Union has occurred though there is a sequestrum present : the marked osteoporosis of the carpal bones.

The first group, *i.e.*, the clean bullet wound, merely require toilet of the entry and exit wounds, and dressing, unless there is continued hæmorrhage. Infection is rare in such wounds and usually not serious. In the second group of cases the exposure of the damaged soft parts which is necessary usually results in the finding and extraction of the foreign body. Where small fragments have produced considerable tissue damage, and then ricocheted to a position where their extraction would be difficult, they may be safely left (Fig. 70B).

Penetrating Wounds of Joints

These are commonly associated with fractures and are treated on the same basic principles as compound fractures. A few special points should however be made with regard to their handling.

An open wound of a joint may arise from

1. Penetration from bullets or other missiles.
2. Perforation by sharp objects.
3. Heavy blows with objects such as a hammer striking the joint tangentially.
4. Gross deformity and dislocation of a joint rupturing the capsule, and its other integuments.

out until the conditions for interference and after-care are stable and satisfactory; in other words, until a man has reached a stable unit. The same arguments hold in civil life, and procedures such as the closure of a compound fracture which would be perfectly safe if the patient were to be nursed in a ward must be altered if the patient is to be evacuated, or removed from full surgical care. Under these conditions wounds which might normally be closed are treated by the closed plaster method, *i.e.* lightly packed and left open. This is not necessarily a fatal step, though it inevitably increases the risk of infection, for the wound can be closed by secondary suture, as soon as conditions permit, and this is remarkably successful.



FIG. 70A Satisfactory union of fracture in spite of the inclusion of many foreign bodies.

Because of evacuation risks the plaster must be a particularly stable one to give full support to the fracture and to the soft tissues. In addition it must provide a ready access to the wound in an emergency, and if possible the inspection must not disturb the fixation of the part. Two particular plasters have been developed which fulfil these conditions, the thoraco-brachial plaster for the upper limb, and the Tobruk plaster for the lower limb. These are described in the chapters on fractures of the humerus and fractures of the femur (pp. 321 and 509).

Secondary suture can be carried out at any time, provided that the patient's general condition is good, and there is a clean tissue bed. In the later stages granulation tissue may have to be removed. A chemotherapeutic umbrella, based on the bacterial sensitivity of the organisms swabbed from the wound is essential. Undercutting the flaps to approximate the skin must be done with care, particularly if the wound is infected. Closure over avascular or infected bone should not be attempted, though suture over bare bone in the first week is often successful.

CAUSES OF FAILURE WITH SECONDARY SUTURE.
1. Excessive tension in the skin flaps.

2. Inadequate hæmostasis.

3. Heavily infected wounds. Do not suture when the patient has a temperature or when œdema is present around the wound.

4. Poor general condition of a patient. Maintain the hæmoglobin above 80 per cent. and give full diet.

The advantages to be gained from the early closure of a wound are many, chiefly the avoidance of undesirable adhesions, the healthier scar obtained, and the possibility of earlier and safer interference if subsequent procedures such as bone grafting have to be carried out.

Compound fractures from missiles. No new complications are raised by this form of injury, but the common complications of compound fractures are met with in an exaggerated form. Soft tissue damage may be heavy, particularly on the side of the exit wound. Comminution in injuries to the shaft of a bone may be marked and there may be considerable loss of bone, while foreign bodies may be widely scattered through the soft tissues. In contrast to this a neat hole may be drilled by a high velocity bullet through the cancellous end of a bone with relatively little damage. In general, small metallic foreign bodies without gross tissue injury may be neglected. They

should be removed if visible or palpable in the general debridement of the wound, but should not be specially sought for in tissues at a distance from the wound. Metallic fragments do not hinder union and may be incorporated in the callus (Fig. 70A). Larger metallic fragments should be removed if they are readily accessible. They should be sought for specially if :—

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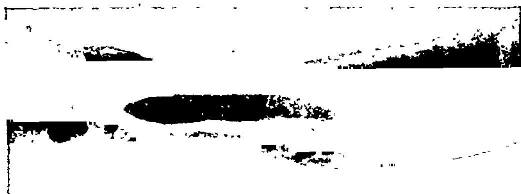


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SIMPLE PENETRATION of a joint by a clean sharp object may be treated expectantly with immobilisation. Where the track is soiled and irregular it should be cleanly excised. If there is doubt of entry of the joint it can be proved by instillation of penicillin into the joint. This may enable synovial tissue to be left intact, or if the joint is open the escape of fluid leads one to the tear.

ARTHROTOMY is best done under a tourniquet, and must be complete and thorough. Boldness is essential. The joint remains sterile for some time and late debridement up to twenty-four hours is safe. All foreign bodies and soiled tissue must be removed, and the joint surfaces sponged clean. The osteotome may be needed to remove flaked and dirty cartilage. The avoidance of infection is more important than the preservation of stability. Remove all damaged ligamentous tissue. Remove all loose bone.

Close the synovial membrane with interrupted stitches if possible. If impossible close the joint cavity with muscle sutured over it. A drain down to this suture line to remove excess synovial fluid and blood is often of value for twenty-four hours. Close the skin and subcutaneous tissue over the synovial suture line if possible. If impossible graft immediately or early. Soft tissue and bone stability are important. Some fractures involving joints, *e.g.*, of the medial malleolus are best fixed with a single screw, and this may be true of the elbow and knee.

Immobilise completely in a plaster with firm pressure over the joint Local instillation with penicillin before closure may be helpful. Systemic chemotherapy is invaluable.

Special Infections. Gas Gangrene and Tetanus

The risks of these infections are not particularly those of fractures, but the depth of wounds involving bone provides the ideal situation under which these infections develop, and so they show a higher incidence in such lesions. The soiling of the wound with dirt is the prime cause of the condition, and it is to be noted that the well-manured soil of the field is richer in such organisms than is street dirt The resistance of the spores of the tetanus bacillus is well known, and they survive a great length of time in the soil once it is infected. In gas gangrene the infection is a double one, but again due to spore forming anaerobes. The characteristic organism is the Clostridium Welchii (*Bacillus perfringens*), which is saccharolytic, and splits the glycogen in the muscles into simpler sugars and ultimately CO_2 and water. This action is followed by the activities of a proteolytic group, *B. sporogenes*, *B. aerogenes capsulatus*, and *Clostridium septique*, which break down the muscle protein with further gas production.

Prophylaxis. The best and most certain prophylaxis is the excision and treatment of wounds on the principles outlined. If this is carefully done the incidence of either condition will be almost negligible in peace-time conditions.

In serving soldiers active immunisation with tetanus toxoid is practised, and the immediate use of anti-toxin is insisted on in all suspicious wounds. For gas gangrene massive doses of antitoxic serum are given to all cases with much muscle damage as soon after wounding as possible.

Tetanus

The symptoms of this condition are due to the absorption of exotoxin from the region of the wound *via* the lymphatics. Symptoms may vary from those of: (1) local tetanus, in which the spasms are confined to the muscles around the wound; (2) tetanus of a limb; to (3) generalised tetanus, according to the degree and rate of absorption of the exotoxin.

The date of onset of the symptoms varies from two days to two months after the injury, depending on the rate of production and of absorption of exotoxin. Associated sepsis increases both considerably. The slowest development is thus seen in wounds infected by spore containing catgut, where the wound may heal by primary intention. The local signs are not peculiar to the condition, being those common to any septic infection. General features such as rise in pulse, and increased nervousness, and apprehension of the patient may be noted, but usually the first feature is the occurrence of spasm in a voluntary muscle. In local tetanus this may be in the neighbourhood of the wound. In limb tetanus one limb may be involved, but the most common manifestation is that from generalised toxæmia when stiffness in the jaw (trismus) and back is complained of. These features are followed in a variable time by the clonic and tonic spasms.

Treatment

PROPHYLACTIC. Tetanus toxoid. Injection of 1 c.c. of the *toxoid*, followed by 2 c.c. in three to six weeks' time, and 2 c.c. in six months, gives an immunity which lasts three years. Omission of the third dose reduces the immunity to one year's duration.

For wounded patients antitoxin offers limited protection for three weeks. Three thousand units are given, followed by a further 3,000 units in twenty-one days if suspicious factors are present. The two methods of active and passive immunity can be practised together in a fresh case if desired. Anaphylactic phenomena will be avoided if the injection is made while the patient is under ether anæsthesia. In any case an antihistamine drug should be at hand to combat it.

CURATIVE. The wound if draining freely should be left alone. Indications for treatment of the wound are provided by general factors, previously discussed, and not by the presence of tetanus alone.

Antitoxin forms the basis of treatment and is given by all routes except the intrathecal. When it was believed that the absorption of the toxin was neural, this route was thought to have advantages. One hundred thousand units are given intravenously at once, and followed by maintenance doses of 20,000 units intramuscularly, or intravenously. Over 500,000 units may be used in such treatment.

GENERAL TREATMENT. Sedatives are necessary to control the fits, and any surgical procedure must be given under some form of general anæsthesia, or the stimulation will provoke another fit. Complete quiet and absence of all disturbance must be assured in the nursing. The sedatives must be adapted to suit the case. Large doses of chloral, paraldehyde by mouth and rectally, intramuscular luminal, morphia, or even intravenous pentothal have all been used, according to the severity of the case. Morphia is probably the most useful standby, but cannot be used over long periods. Maintaining the patient's general condition by adequate nourishment is often difficult, and intravenous fluids and glucose may be given, combined with nasal feeds when the patient is under suitable sedatives.

The most hopeful recent development is the use of the muscle relaxants of the curare group. The control of respiratory paralysis provided by the iron lung enables the drug to be pushed so that the spasms can be controlled, while respiration can be maintained. The effective use of this method demands considerable experience, but remarkable recoveries of the more severe cases have occurred and the availability of an iron lung for the treatment of tetanus is as important as it is for the treatment of poliomyelitis.

PROGNOSIS. This varies with the date of onset of the symptoms. The more delayed this is the better the outlook. The more localised the spasms also the better the outlook. Generalised tetanus is always of grave significance but not necessarily fatal.

Gas Gangrene

Cl. welchii is a spore forming anaerobe like tetanus and has a similar habitat. It is invariably present in gas gangrene and is accompanied by a variety of other anaerobes, some capable of symbiotic activity, and by the more common aerobes. It is the chief producer of gas, being mainly saccharolytic, but is also proteolytic. It can only live under anaerobic conditions, and an effective blood supply is the best barrier to its progress. It follows that the effective blood supply of the wound area is most important, and any local vascular damage or general vascular failure from shock may be of great significance in the spread of the condition.

Clostridium œdematiens though non-invasive, produces extensive œdema, and an absorbable exotoxin. *Clostridium septicum* similarly produces œdema and an exotoxin, but can actively invade the tissues. *Cl. Fallax, Cl. Histolyticum, Cl. Sporogenes* are spore-bearing anaerobes commonly found in association with gas gangrene infections.

The extension of the disease is dependent on the invasion of muscle, and fascial barriers offer a short check to its course. The importance of the blood supply, long ago pointed out by Larrey, is seen in the increased incidence in severe contused and crushed wounds. The disease may localise itself in

1. A wound area { Contamination. / Anaerobic cellulitis.
2. A muscle belly.
3. A muscle group.
4. A segment of a limb,

each giving opportunity for surgical treatment.

The wound area. The organism may be found in a granulating wound as a harmless contaminant. If active there is the formation of local gas, but on account of reduced virulence or active granulation tissue there is no further spread and an absence of systemic effects. The characteristics of the wound are those of gas gangrene in a subacute form. These are pallor, swelling and

œdema of the wound edges, a thin evil-smelling, brownish discharge, with a peculiar fœtid odour, some crepitations in the surrounding tissues, and bubbles in the wound. The condition is confined to the subcutaneous tissues and requires adequate drainage and general therapy.

Localised infections in muscles. The discharge and odour are present. Gas formation is increased and the muscle colour varies from a dark red to a greenish black. The tissues are swollen and œdematous, tense and crepitant. Radiological examination may reveal gas, but must not lead to an erroneous diagnosis from the inclusion of outside air in the wound. The general features are a toxæmia out of proportion to that to be expected. The temperature is variable, but the pulse is running and rises rapidly and disproportionately to the temperature. Pain from the pressure of swollen tissues is severe. Colour changes in the skin of a necrotic type may be seen at a little distance from the wound edges. The patient is often mentally disturbed and restless. The diagnosis of the condition under closed plasters is obviously important and may be indicated by early and severe signs of pressure inside the plaster and severe pain of a burning character at the site of injury.

Generalised infections. Severe toxæmia may be rapidly followed by septicæmia, but fulminating forms are seen, in which a general septicæmia develops so rapidly that few changes may be noted in the wound. These patients are pale, cold and mentally alert. There is a subnormal temperature and a running pulse. Vomiting, dilated pupils and air hunger usher in the end.

Treatment. PROPHYLACTIC. Cases which are likely to develop the condition, *i.e.*, those in which there is muscle damage, contamination or delay in surgical treatment or associated vascular damage, should receive as soon as possible after wounding a dose of antitoxic serum. This should contain 9,000 units of *Cl. Welchii*, 4,500 units of *Cl. Septicum*, and 3,000 units of *Cl. Œdematiens* antitoxin. This is given intramuscularly or intravenously.

The immediate treatment of the wound by excision is followed by the local application of penicillin and a general course of chemotherapy suitable to severe infections (p. 89). Massive doses of serum are given intravenously. Doses of 27,000 units of *Cl. Welchii* antitoxin with other antitoxins in proportion are given every six hours.

SURGERY. This is of value only in the localised forms, and its prime object is the excision of all infected tissue, leaving the minimum of muscle tissue exposed. For [illegible]
confined to one musc[illegible]
the group are the lim[illegible]
the knee or elbow m[illegible] Excision is
followed by light powdering of the wound with sulphonamides and penicillin, light packing of the wound, and immobilisation.

PROGNOSIS. The prognosis varies with the amount of muscle infected before treatment is introduced, and the constitution and general condition of the patient. In localised infection it is hopeful, but in any widespread condition the outlook, in spite of blood transfusion and adequate serum, is poor.

FURTHER READING

Compound Fractures

EHALT, W. "Behandlung der offenen Bruche der Langen Rohrenknochen." Wilhelm Maudrich, Vienna, 1938.

HUDSON, O. C. "Multiple Fractures," *J. Bone and Joint Surg.*, 1940, 22, 354.

TRUETA, J. "The Principles and Practice of War Surgery," London, 2nd ed., 1943 (Hamish Hamilton and Wm. Heinemann).
DAVIS, A. G. "Primary Closure of Compound Fracture Wounds," *J. Bone and Joint Surg.*, 1948, 30A, 405.
SEDDON, H. J. ED. "Wounds of the Extremities," *Brit. J. Surg.*, War Supplement, No. 2.

Infection

MACLENNAN, J. D. "Anaerobic Infection of War Wounds in the Middle East," *Lancet*, 1943, *ii.*, 63.
TOPLEY AND WILSON. "Principles of Bacteriology and Immunity." London, Edward Arnold & Co., 3rd Ed., 1946, *ii.*, 1746.
DE WALL, H. L. "Wound Infection. A preliminary Note on the Combined Clinical and Bacteriological Investigation of 708 Wounds," *Ed. Med. Jour.*, 1943, 50, 571.
REYNOLDS, F. C., and ZAEPFEL, F. "Management of Chronic Osteomyelitis Secondary to Compound Fractures," *J. Bone and Joint Surg.*, 1948, 30A, 331.
CLEVLAND, M., and WINANT, E. M. "Treatment of Non-union in Compound Fractures with Infection," *J. Bone and Joint Surg.*, 1952, 34A, 554.

Tetanus

COLE. "Treatment and Prognosis in Tetanus," *Proc. Roy. Soc. Med.*, 1938, 31, 1205.
SHACKLETON, P. "The Treatment of Tetanus," *Lancet*, 1954, *ii.*, 155.

Gas Gangrene

MEDICAL RESEARCH COUNCIL. "Notes on Gas Gangrene Prevention," *War Memorandum No.* 2, 2nd ed., 1943.
WAR OFFICE. "Use of Gas Gangrene Antitoxin," *Army Med. Dept. Bull.*, No. 30.
PATTERSON, KEATING AND CLEGG. "Experiences in the Prophylaxis and Treatment of Clostridial Infections in Casualties from the Invasion of Europe," *Brit. J. Surg.*, 1945, 33, 74–79.
JEFFREY AND SCOTT THOMSON. "Gas Gangrene in Italy, a Study of 33 Cases Treated with Penicillin," *Brit. J. Surg.*, 1944, 32, 159–167.
CUTLER AND SANDUSKY. "Treatment of Clostridial Infections with Penicillin," *Brit. J. Surg.*, 1944, 32, 168–176.
TOPLEY AND WILSON. "Principles of Bacteriology and Immunity." London, Edward Arnold & Co., 4th Ed., 1955, *ii*, 1770.

CHAPTER X

DELAYED UNION, NON-UNION, MAL-UNION

Union. CLINICAL UNION. When a bone is *rigid to bending stress* in all directions, and this stress produces *no pain at the site of fracture*, and the *callus is no longer tender*, the bone is clinically united. This does not necessarily correspond to the appearance of union radiographically and to wait for this confirmatory evidence is to lose valuable time. The radiograph may, however, be of value in judging the strength of union present and its liability to yield under the continued action of body weight. If satisfactory, all support can be abandoned. If uncertain, a period of observation doing bed exercises is often of value. It is surprising how often a doubtful union appears to become firm under these conditions.

A lesser degree of fixation may be allowed. Thus in the case of fractures of the leg, when there is no fear of rotatory strain, there is no need to fix the knee, and active exercises of the joint may be commenced. Clinical union is the sign for more active employment of the limb.

RADIOLOGICAL UNION. This may be obvious at the time of clinical union, but more often lags behind it. It is often difficult to determine, *e.g.*, in the case of the navicular, and when obvious usually indicates that clinical union has been long established. It is a valuable aid to the assessment of the strength of union and of the occurrence of non-union.

Delayed union. The time which a fracture takes to unite depends on many factors. Thus the particular bone fractured, the particular site involved, the age and general condition of the patient all influence the time taken for repair. We cannot, therefore, assign any fixed period beyond which we can say the union is delayed, for all fractures, but there are periods for each fracture in which union should occur and beyond which we can say that union is delayed.

Non-union. With the passage of time and the development of further change in the bones this may definitely become "non-union." Here we have a visible change in the bone pathology which can be detected in the X-ray, and this can be considered a criterion of non-union. There is, however, no fixed boundary between the two conditions and one merges into the other. The causes influencing the development of either condition are the same, and are as follows :

1. WIDE SEPARATION OF THE BONE ENDS. Several factors may

produce this. Loss of bony tissue in compound comminuted fractures is important. Gross displacement of the parts if left unreduced may produce it. With skeletal traction there is a definite risk that excessive traction may over-separate the bone ends and cause failure of union, while continuous distraction is an even more potent cause of failure.

2. Interposition of soft parts. Muscle and fascia may be turned in between the bone ends, thus preventing their approximation, and forming a barrier to callus formation. Even the blocking of the medullary canal by the impaction of a fragment of compact bone across it may prevent union.

3. Constant movement. This is an important point. The influence of movement on the development of callus has been mentioned. A small degree of movement does not delay healing, but gross degrees of movement will. Small movements tending to impact the fracture ends will encourage union, hence the efficacy of a walking plaster, in some cases of doubtful union of the tibia. It is a mistake to think that a plaster produces complete immobilisation. The degree of movement at the fracture site is often quite surprising.

The ribs are always cited as an example where constant movement does not prevent union. In the ribs the actual movement of the rib ends on each other is small, owing to their fibromuscular attachments. This degree of movement may result in excessive callus, but never in non-union.

A restless patient who will not remain quiet under skeletal traction may cause such bones as the femur to fail to unite, and in certain cases may justify operative fixation and plaster.

4. Infection. The disastrous effects of infection in delaying union need no reiteration here.

5. Loss of the blood supply. In certain bones this may produce avascular necrosis of a fragment of bone. This commonly occurs to small fragments in comminuted fractures and is of no importance. In certain bones such as the navicular and the upper end of the femur the loss of blood supply may involve the whole of one surface of the fracture, and then delay in union must occur while the bone is revascularising, or, if this fails to occur, absolute non-union will be established. Double fractures of a long bone inevitably delay the healing of one fracture, usually that fracture separated farthest from the nutrient artery, which thus has a reduced blood supply.

The effect of the widespread stripping of the bone ends in a grossly displaced fracture must not be forgotten. This often results in avascular necrosis of surface cells at the ends of the bone, and reduced callus formation, leading to atrophic non-union.

6. Local or general disease. This may influence union. A positive Wassermann may delay union till adequate treatment has been carried out. Most local conditions of bone, such as cysts, tumours, and the other conditions outlined under the causes of pathological fractures do not cause non-union, though they cause delay in union. Scurvy, tabes and advanced malignancy seem to be the only conditions causing absolute non-union.

7. Buried foreign bodies. In certain cases the use of Lanes' plates or wire leads to a mild inflammatory reaction around them with hyperæmia of the bones and decalcification. This may be the cause of failure to unite. The reaction is not so noticeable with bone pegs or grafts and is due to some specific effect of the metal. On the other hand compound fractures due to bullet wounds often heal well in spite of metal being scattered through the bone, if no infection occurs.

The effect of synovial fluid on union has been called in to explain non-union in navicular and patella fractures, but it can be said with confidence that it does not delay or prevent union.

The influence of the type of fracture must be mentioned. Transverse fractures have a small area of bone in contact, have often less periosteal disturbance, and so throw out less callus and unite more slowly than oblique fractures. This effect is often seen with fractures which are treated by open reduction, the amount of callus formed being small, and making a radiological decision on the strength of union difficult. When in doubt rely on the clinical signs of union.

Types of Non-union

1. Fibrous.
2. False joint formation.
3. Absolute
   - (A) Atrophic (Fig. 73).
   - (B) Hypertrophic (Fig. 72).

Fibrous union occurs normally in certain bones such as the skull and the patella, and it may occur in many other fractures and allow of full function, *e.g.*, fractures of the clavicle and the navicular. In certain bones, such as the long bones, it is insufficient and bony union must be obtained. Fibrous union can only be satisfactory where there is no serious bending strain.

False joint formation. It has been mentioned in the chapter on the healing of fractures that the amount of cartilage at the fracture site is related to the amount of shearing strain which the fracture undergoes while callus is forming. Excessive movement may produce excessive cartilage, and under the influence of further movement this

may form itself into a false joint with a central cavity containing fluid, and surrounding thickening in the fibrous tissue resembling a capsule. It is to be noted that only shearing strains produce this effect. Compression strain encourages union. False joint formation occurs commonly in tabetics in whom the loss of sensation encourages abnormal movements at the fracture site. False joint formation is much more common in active young men than in old

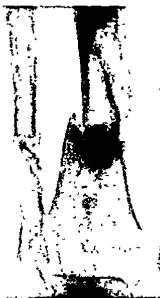


Fig 71. False joint formation in fracture of the lower third of the tibia. The bony sclerosis on the distal side is well marked, and into this the rounded proximal end fits

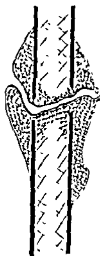


Fig. 72. Hypertrophic type of non-union. There is a good callus reaction, but there is a line of non-union across this. This is the type of non-union suitable for Beck's bone drilling.

men, and is very rare in women. If the limb is used the modifications which occur in the bone ends and the surrounding structures make it very closely resemble a normal joint. The bone end rounds off on one side, and expands on the other to form a bearing surface. These surfaces are covered in cartilage and fluid appears between them, while the fibrous tissue around the bone ends comes to resemble a capsule (Fig. 74).

Absolute non-union This is usually a very weak type of fibrous union. In the *atrophic type* (Fig. 73) it is shown radiologically by the rounding off of the bone ends, and the closure of the marrow cavity with a thin layer of compact bone while a considerable gap separates the bones In the *hypertrophic* group of cases the marrow cavity closes off with a layer of sclerotic cancellous bone and a

broader softened line is left between the two fractured surfaces. In the hypertrophic type (Fig. 72) there has been a good callus reaction and the ends of the bones are surrounded as a rule by excess callus, but for some reason the callus fails to unite. In the atrophic type there is very little callus reaction at all, and the outlook is more serious. This condition is fortunately the less common of the two. When either of these conditions is established any hope of union by other than operative means must be abandoned.



Fig. 73. *Atrophic type of non-union. There is little callus reaction, and the bone ends have rounded off and been partly absorbed. This is unsuitable for Beck's drilling, but may be bone grafted.*

Treatment. Delayed union. General treatment is the same in all cases, and consists of efficient nursing, together with an adequate diet in which all the vitamins are present. To stimulate union a variety of agents from egg-shell to parathormone have been tried and vaunted, but on clinical and experimental grounds it is extremely unlikely that they have the slightest effect. Adequate calcium and phosphorus are, for example, obtained from the decalcification of the rest of the skeleton, the amount stored there, compared with the amount required for the callus and the amount ingested from any special diet, being enormous.

Special treatment. This is directed to the discovery of the cause and, if possible, its removal. The treatment of a positive Wassermann reaction will usually result in union in a short time. In the lower limb the use of a walking plaster, or some form of weight



Fig. 74 Established non-union with false joint formation following a fracture of the clavicle. The condition was consistent with excellent function.

bearing, will often promote rapid union. In the femur the release of the traction weights is often the signal for union to commence. Adequate length of immobilisation will result in the union of many fractures of the navicular.

Where possible the use of the affected limb should be encouraged. The arm should be given the appropriate plaster, and the leg fitted with a walking plaster or a calliper. If after some time there is no union and the X-ray shows increasing sclerosis of the bone ends, absolute non-union is established and operative interference will be necessary to procure union.



Fig 75. Long standing ununited fracture of the body of the navicular, showing the smooth surfaces and well-marked sclerosis on either side of the fracture line. Non-union is established and absolute.

Absolute non-union. All operative interference is directed to three ends.

1. The opening up of the bone ends.
2. The formation of a fresh hæmatoma.
3. Improved fixation of the parts.

Certain treatments such as the injection of whole blood around the bone ends, or of dilute hydrochloric acid have occasionally been successful, because they have fulfilled these conditions in part, but in general they are unreliable.

The simplest method of producing the conditions above is to retraumatise the fracture area by manipulation and hammering under an anæsthetic. This may be combined with a tourniquet above the fracture site compressing the veins only, which is maintained for some twenty to thirty minutes to encourage the formation of a larger hæmatoma. After such treatment adequate fixation is secured by plaster, and in suitable patients weight bearing is encouraged. This will cause union in a few cases, but it is better regarded *as a method of hastening delayed union than a method of treating* non-union.

If this method fails or is unsuitable, the next grade of interference is provided by Beck's bone drilling. This can be done under local anæsthesia if necessary, and is considerably aided by the use of a mechanical drill, either pneumatic or electric. The skin over the fracture is satisfactorily sterilised and anæsthetised. Two incisions are made at suitable sites. A small bone drill is then inserted at a



FIG. 76. Beck's bone drilling. Through two small skin incisions, made to avoid soiling the drill by contact with the skin, the bone is drilled in the direction indicated by the interrupted lines.

convenient point, and by repeated drillings and partial withdrawals the bone ends are perforated in numerous directions. The number of perforations made will depend on the size of the bones and their accessibility. Both ends of the bone are dealt with in the same way, and the fracture then treated as a fresh fracture, and reset in a

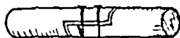


FIG 77. Step cut operation.



FIG. 78. Double oblique method of joining bones.

plaster cast. This method is very successful in selected cases, notably the hypertrophic type of non-union. For it to succeed the bone ends must be capable of being brought into apposition. Where there are two bones to be considered this may mean that an osteotomy must be done on one of them. This is often necessary in the leg, where the fibula unites well and the tibia does not. For any



FIG 79. Usual method of inserting a sliding tibial graft. The long and short portions of the bone freed by the saw cut are reversed in their bed.



FIG. 80. Correct method of grafting. One saw cut is slanting, leaving a wedge of bone free which is slid downwards and fixes firmly into the lower part of the bed.

method to be successful the fibula must be divided first to allow the two ends of the tibia to come into contact. Cases of atrophic non-union or in which there is an obvious inclusion of soft parts are unsuitable for this method of treatment, and in cases in which it has failed other methods must be adopted. The next step usually considered is the amputation of the bone ends, and their approximation, which can only be considered if one is prepared to sacrifice the length of the bone to some extent. This is only possible in the arm, and here, owing to technical difficulties with grafts and plates, it is often a useful manœuvre. Re-union of the bones is accomplished by the "step-cut" method (Fig. 77) or by cutting both ends obliquely (Fig. 78) and screwing them together.

Rarely when mere separation of the bone end has been the cause of non-union, placing the bones in correct relation and plating them may be sufficient. Plates may be combined with grafts to obtain the advantages of both. In general, pure grafts will be found most satisfactory.

BONE GRAFTING

The final resort, and the most satisfactory method in most cases, is bone grafting. This provides fresh bony material, demands an adequate opening up of the bone ends and the formation of a fresh hæmatoma around them, and provides internal fixation. The success of bone grafting as a method of obtaining union has led to its wide use for other conditions. Indications for its use are present when :—

1. Absolute non-union is established (atrophic or hypertrophic).
2. False joint formation.
3. Obvious loss of bone which will delay or prevent union is present
4. Fractures in which difficulty is expected or non-union is common, *e g* , fractures of the medial malleolus with displacement or of the femoral neck,
5. Delayed union in certain cases.

The material used for grafting may be obtained from the bone that is grafted or from another site, such as the iliac crest or from a bone bank. The increased operating time taken by making a second incision is offset by the added strength of the material gained and the fact that the injured limb is not further weakened, but has osteogenic material added to it. In covering large defects these advantages are important.

Bone grafts may be.

1. Cancellous chip grafts
2. Inlay grafts.

3. Onlay grafts.
4. Massive sliding grafts.
5. Combinations of grafts and metallic fixation.

The cancellous chip method has been derived logically from the fact that the earlier the graft is re-vascularised the sooner sound



FIG 81. Non-union Compound comminuted fracture of tibia.



FIG. 82. Union obtained by sliding bone graft fixed by two screws. A.P. view (inlay graft).

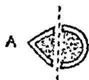


FIG. 83. Lateral view of same case.

union of graft and bone will occur. In a compact graft only surface cells survive. In a chip graft the surfaces are large, and many more cells survive, with a consequent rapid formation of new bone and consolidation of the chips. The disadvantages are the absence of the rigidity provided by other methods and its consequent unsuitability in many situations. The chips are usually derived from the injured

bone or the wing of the ilium. A modified form has been used in arthrodesis with success. They may be combined with metallic fixation.

INLAY GRAFTS. The sliding graft is the principal example of this



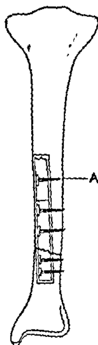


FIG. 84. The sliding graft—the small lower fragment is replaced above the graft and fixed with a single screw (A).

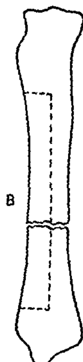


FIG 85. The Massive graft :—
A. Complete division of bone by saw.
B. Area split and removed.

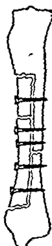


FIG. 86. The sections reversed and screwed in position.

[illegible]

screwed into position. The disadvantage of the method is the fact that the curves of the graft do not correspond to the curves where it is moved, and so one end of the graft must always be sunken. Further in order to get firm fixation of the graft it is necessary to

taper the graft (Fig. 80), both from above down, and from side to side, so that it may be firmly impacted into its bed by the screws employed to hold it (Fig. 84).

ONLAY GRAFT. This graft is screwed to the surface of the bone. This has the slight disadvantage of increasing the bulk of the bone. but does not necessitate the weakening of the bone with saw cuts.



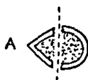
FIG. 87. Non-union of a fracture of the tibial shaft treated by massive sliding graft.

By proper trimming of the graft and of the bed on which it is to lie it can be adapted to any surface. By reversing the graft so that the cancellous surface lies outwards, flat surfaces of compact bone can be obtained to work with and the cancellous outer surface provides better osteogenesis.

MASSIVE SLIDING GRAFT. This has been worked out in an endeavour to obtain a mechanically sound method. It is essentially similar in principle to the sliding graft, but the whole thickness of the bone is split in section and not as a groove. By this means a level surface of bone is obtained to work with, and reversal of the bone fragments does not upset alignment (Figs. 85, 86). It is the soundest method mechanically, though a rather extensive procedure.

bone or the wing of the ilium. A modified form has been used in arthrodesis with success. They may be combined with metallic fixation.

INLAY GRAFTS. The sliding graft is the principal example of this



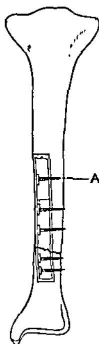


FIG 84 The sliding graft—the small lower fragment is replaced above the graft and fixed with a single screw (A).

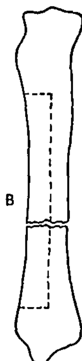


FIG. 85. The Massive graft :—
A. Complete division of bone by saw.
B. Area split and removed.



FIG. 86. The sections reversed and screwed in position

method Here a long channel is cut in the bone crossing the fracture line so that two-thirds of its length lies to one side of the line and one-third to the other. The fragments are freed and then reversed and screwed into position. The disadvantage of the method is the fact that the curves of the graft do not correspond to the curves where it is moved, and so one end of the graft must always be sunken. Further in order to get firm fixation of the graft it is necessary to

alignment is necessary in the lower limb, where the relation of the bones to the line of transmission of the body weight is of great importance. In the arm shortening, rotation, and angulation may be overlooked if they are not gross. In the forearm these defects will lead to loss of pronation and supination. Rotation produces a serious disability in the fingers.

A fracture may be mal-united, but produce no interference with function, in which case before treatment is decided upon one must ascertain if the deformity is likely to increase, or to produce other disabilities, such as traumatic arthritis. In the young the bones will spontaneously correct quite large deformities, and unless the lesion is very gross it is wise to postpone interference till growth has ceased. In adults there is little spontaneous correction.

TREATMENT. This may be necessary at the following stages.

1. Early, when the callus is soft.
2. After consolidation of the callus.
3. In late cases when secondary effects have arisen.

In the early stages the correction of the deformity may be brought about by any of the methods used for fresh fractures, *i.e.*, manipulation, continuous traction, or open operation.

MANIPULATION. The length of time during which this can be carried out varies with different lesions. In the wrist one may refracture and reset a Colles's fracture up to ten weeks after the original injury. The callus around a femur will not be firm for six to eight weeks, and similarly a fracture of the tibia and fibula may be bent up to five weeks after the injury. The best gauge of the possibility of manipulation is the X-ray. The nearer the fracture is to the joint the more difficult it is to manipulate, and also the more rapid union is likely to be. It is very important to get correct alignment of a third degree abduction fracture of the ankle at once and not allow early weight bearing which may disturb it. Following a manipulative correction for recurrent deformity, a fresh plaster is applied.

Manipulation can be carried out under the screen, which is a great help in correcting the angulation of long bones accurately. In fresh cases the freedom of mobility of the fracture ends on each other may cause some trouble in manipulation, but if a period of two to three weeks is allowed to elapse with the ends in contact, sufficient fixation will have occurred to prevent the bones moving laterally on each other, but not sufficient to prevent correction of angulation, which may then be done with great precision.

A very satisfactory method of correction in suitable cases is provided by wedging the plaster. This enables an angular deformity

All methods should be done under radiological control to be certain that alignment is perfect before being finally closed. The use of an electric or compressed-air driven saw and drill is essential. "No touch" technique should be employed throughout. All the methods are usually successful. Clinical union is established in a varying time after three months from the operation. The fate of the graft has already been discussed (p. 22).

Grafts should not be carried out on infected fractures until at least six months from the date of healing of the wound. Preliminary skin grafts may be necessary to obtain suitable skin through which to work. The advantage of employing a plate in addition to the graft is the additional strength given to the fracture site, which facilitates the use of cancellous bone or chip grafts. The chief advantage of compact bone is that it provides firm internal fixation as well as a new source of bone.

The advantages of freedom from the necessity of external support are discussed on p. 104. Where Lane used plates for non-union, Beck's bone drilling is often equally effective. Where non-union and displacement co-exist grafts alone are not always satisfactory.

Failures of grafting. The chief causes of failure in bone grafting will be found among the following errors or accidents.

1. Sepsis. To be avoided by awaiting an adequate time for tissue infection to subside, i.e., three to six months. Obtaining sound skin cover through which to operate, the use of chemotherapy.
2. Application of the graft under strain. Notably in grafting the bones of the forearm. To avoid this the use of a plate and graft together is sometimes advisable.
3. Inadequate nutrition of the graft. Failure to prepare the graft bed adequately and excise avascular bone and fibrous tissue. Chip grafts of cancellous bone survive best and may be used preparatory to a cortical graft in difficult situations.
4. Failure to immobilise the graft efficiently.
5. Lack of protection of the graft before union is solid.

Mal-union

This may take the form of

1. Shortening. Due to loss of bone or overlap of the bone ends.
2. Angulation. Due to too early use or incomplete reduction.
3. Rotation. Due to failure to align the limb correctly.
4. Excessive callus (see Fig. 52).

The importance of these various deformities depends to a great extent on whether the lesion is in the upper or lower limb. Accurate

function in late lesions of the hip, ankle, and other joint, are outside the scope of this book.

Excessive Callus

The amount of callus formed depends on :

1. The size of the hæmatoma.
2. The amount of comminution of the bones.
3. The amount of movement at the fracture site during retention.
4. The bone fractured. Membrane bones repair by fibrous tissue.

Excessive callus is rarely a drawback, but it may be cosmetically undesirable in such bones as the clavicle. In the arm the radial nerve may be involved in the organising callus and paralysis produced. Either of these reasons may call for surgical interference. In the neighbourhood of joints excessive callus may interfere with the joint movement. It usually slowly adapts itself to the situation and full movement is restored.

FURTHER READING

GALLIE and ROBERTSON. "The Repair of Bone," *Brit. J. Surg.*, 1919, **7**, 211.

CAMPBELL. "Malunited Fractures," *Surg. Gynec. and Obst.*, 1938, **66**, 466.

KELLY, R. E. "Application of Wedge Principle in Fashioning a Tibial Bridge Graft," *Brit. J. Surg.*, 1923, **10**, 232.

ALBEE. "Bone Graft Surgery." New York, 1915.

WELDEY. "Ununited Fractures Treated by Long-axial Drilling of the Fractured Bone Ends," *Brit. J. Surg.*, 1914, **2**, 423. (Anticipated Beck, but drilled axially with wide exposure.)

BECK, A. "Zur Behandlung der verzögerten Konsolidation bei Unterschenkelbruchen," *Zentralbl. f. Chir.*, 1929, **56**–2, 2690.

LANE, W. ARBUTHNOT. "The Operative Treatment of Fractures," London, 1914, 2nd ed. The Medical Publishing Company.

ARMSTRONG, J. H. "Bone Grafting in the Treatment of Fractures," Edinburgh, 1945. E. & S. Livingstone.

ELLIS, V. H., LANGSTON, C. H. and ELLIS, J. S. "Failures in Cortical Bone Grafting," *Lancet*, 1947, **2**, 128.

RAY, R. D., *et al.* "Bone Regeneration," *J. Bone and Joint Surg.*, 1952, **34A**, 638.

HAM, A. W. "Some Histo-physiological Problems peculiar to Calcified Tissues," *J. Bone and Joint Surg.*, 1953, **35A**.

CAMPBELL, C. J., *et al.* "Experimental Study of the Fate of Bone Grafts," *J. Bone and Joint Surg.*, 1953, **35A**, 332.

WEAVER, J. B. "Experience in the Use of Homeogenous (Bone Bank) Bone," *J. Bone and Joint Surg.*, 1949, **31A**, 778.

NICOLL, E. A. "The Treatment of Gaps in Long Bones by Cancellous Insert Grafts," *J. Bone and Joint Surg.*, 1956, **38B**, 70.

to be corrected with almost mathematical precision. The application of the method to the tibia is shown on page 553.

GRADUAL CORRECTION. This is difficult to control in many cases but it may be attempted by corrective padding inside a plaster cast, or using heavy skeletal traction for a short time, or the use of adjustable pressure pads, and suchlike manœuvres. In the long bones it may be done by making a circular cut in the plaster case at the level of the fracture and then wedging the plaster at the appropriate spot. When the correction is shown to be radiologically correct the wedges and gap are plastered over.

OPERATIVE CORRECTION. This is reserved as a rule for solidly united cases. An osteotomy at the site of an old fracture is apt to be followed by non-union, especially if treated by any form of



FIG. 88. Mal-union of the Radius.



FIG 89. Correction of the angulation by an oblique osteotomy and fixation with a single screw.

traction, so care must be taken in the selection of cases. Oblique osteotomies are to be preferred to transverse ones in which the usual difficulties of transverse fractures are likely to complicate matters, *i e.*, lateral displacement and slow union.

LATE CASES. After a period of six to twelve months the joints become adapted to their new positions, joint surfaces alter in outline and ligaments elongate and contract. Any attempt to alter the alignment results in the imposition of a further strain on the joint similar to the first to which it must adapt itself once again. This will aggravate rather than relieve any traumatic arthritis already present, so where this is a genuine disability an arthrodesis is to be preferred to any attempt to correct the alignment.

In young patients these arguments do not hold, as the joints are more adaptable, and serious deformities should be corrected, leaving the finer details of correction to growth.

Shortening may be corrected by an oblique osteotomy and traction, or by the insertion of a bone graft. Rotation is the most difficult to correct as it requires a transverse osteotomy with its disadvantages, or a very well-planned oblique one.

Various complicated orthopædic procedures to improve the

function in late lesions of the hip, ankle, and other joint, are outside the scope of this book.

Excessive Callus

The amount of callus formed depends on :

1. The size of the hæmatoma.
2. The amount of comminution of the bones.
3. The amount of movement at the fracture site during retention.
4. The bone fractured. Membrane bones repair by fibrous tissue.

Excessive callus is rarely a drawback, but it may be cosmetically undesirable in such bones as the clavicle. In the arm the radial nerve may be involved in the organising callus and paralysis produced. Either of these reasons may call for surgical interference. In the neighbourhood of joints excessive callus may interfere with the joint movement. It usually slowly adapts itself to the situation and full movement is restored.

FURTHER READING

GALLIE and ROBERTSON. "The Repair of Bone," *Brit. J. Surg.*, 1919, 7, 211.

CAMPBELL. "Malunited Fractures," *Surg. Gynec. and Obst.*, 1938, 66, 466.

KELLY, R. E. "Application of Wedge Principle in Fashioning a Tibial Bridge Graft," *Brit. J. Surg.*, 1923, 10, 232.

ALBEE. "Bone Graft Surgery." New York, 1915.

WELDEY. "Ununited Fractures Treated by Long-axial Drilling of the Fractured Bone Ends," *Brit. J. Surg.*, 1914, 2, 423. (Anticipated Beck, but drilled axially with wide exposure.)

BECK, A. "Zur Behandlung der verzögerten Konsolidation bei Unterschenkelbruchen," *Zentralbl. f. Chir.*, 1929, 56-2, 2690.

LANE, W. ARBUTHNOT. "The Operative Treatment of Fractures," London, 1914, 2nd ed. The Medical Publishing Company.

ARMSTRONG, J. H. "Bone Grafting in the Treatment of Fractures," Edinburgh, 1945. E. & S. Livingstone.

ELLIS, V. H., LANGSTON, C. H. and ELLIS, J. S. "Failures in Cortical Bone Grafting," *Lancet*, 1947, 2, 128.

RAY, R. D., *et al.* "Bone Regeneration," *J. Bone and Joint Surg.*, 1952, 34A, 638.

HAM, A. W. "Some Histo-physiological Problems peculiar to Calcified Tissues," *J. Bone and Joint Surg.*, 1953, 35A.

CAMPBELL, C. J., *et al.* "Experimental Study of the Fate of Bone Grafts," [illegible] 5A, 332.

[illegible] he Use of Homeogenous (Bone Bank) [illegible] 1949, 31A, 778.

[illegible] The Treatment of Gaps in Long Bones by Cancellous Insert Grafts," *J. Bone and Joint Surg.*, 1956, 38B, 70.

CHAPTER XI

"PATHOLOGICAL" FRACTURES[1]

There is of course no such thing as a "*spontaneous*" *fracture* if the word is used in the same sense as in "spontaneous" combustion. All fractures demand a certain degree of bone stress, but in the group of so-called "spontaneous" or pathological fractures the stress applied is considered by the patient to be one which he normally would be able to support. The stress producing the fracture may therefore be applied by:

1. Body weight or limb weight.
2. Muscular contraction.
3. External force which would normally be comfortably borne.
4. Fatigue.

Repeated stress by a process of summation similar to fatigue in metal may produce a fatigue fracture of bone. In this case the reparative powers of the bone often keeps pace with the disintegration and no fracture as such is noted by the patient. The application of the term "spontaneous" to such fractures may therefore be questionable, but it falls within the wide category implied by the term "pathological," of a break in continuity of bone without adequate cause being apparent to the patient, though it will not be discussed here.

The primary factor responsible for fracture from body weight, limb weight or mild external force is some local weakening of the skeleton which may occur as a result of:

1. General skeletal disease (*a*) congenital.
   (*b*) acquired.
2. Local bone disease.
3. Avascular necrosis of bone.

Similar lesions may facilitate fracture from muscular violence, but "spontaneous" fractures from excessive muscle tension have been seen in normal bone following epileptic fits and more recently in the use of electro-convulsion therapy. This latter risk is now happily avoided by the use of curare or its derivatives. *Incoordinate muscular activities in conditions such as tabes and syringomyelia* may also play a part.

[1] Courtesy of Harvey and Blythe. This chapter with little alteration appeared in *Medicine Illustrated*, 1952, 6, 101.

Bony dystrophies

Frequent multiple "spontaneous" fractures in childhood due to congenital bony abnormalities fall into three groups :

1. *Osteogenesis imperfecta*, a non-hereditary condition in which the child is frequently still-born or if it survives, there is some possibility of recovery if the child can be carried through the early years of life ; there is, however, a tendency for non-union to become established at one or more fracture sites.
2. *Fragilitis ossium*, a hereditary disease accompanied by blue scleræ, otosclerosis and joint laxity in which a tendency to fracture may persist until quite late in life.
3. *Osteosclerosis fragilus* (" marble bones " or Albers-Schönberg disease) in which there are dense lime rings in the metaphyseal region and excessive calcification in the periarticular structures with a predisposition to fracture.



Fig. 90. Osteogenesis imperfecta. Marked osteoporosis, gross deformity, traces of old fractures, and a recent fracture, in a patient aged fifty.

The Vitamin Deficiencies

Vitamin C

There is no need to detail the characteristic features of scurvy. In the infant spontaneous separation of the epiphysis may occur though more often the rate of new bone formation and the blood-distended periosteum retains the epiphysis firmly in position.

Vitamin D

Deficiency results in weakening of the bone structure producing slow yielding and therefore unsuspected bone collapse in weight bearing cancellous bone, notably the spine, which is more common than " spontaneous " fracture. The deformities, however, may become severe and these may lead to fracture later in life. Deficiency of vitamin D may occur as a result of inadequate diet and is classically seen in hunger osteodystrophy or it may be precipitated by the extra

demands of pregnancy (pregnancy osteomalacia). Failure to absorb *adequate vitamin D may occur in idiopathic steatorrhœa* and there is an odd group of patients in whom there are all the features of vitamin D deficiency, but a failure to respond to adequate vitamin D therapy ("Milkman's" syndrome). The exact cause of the resistance to vitamin D therapy is ill understand. A rare, but somewhat *similar condition,* is *the* Fanconi syndrome in children which is associated with rickets osteomalacia and a renal disturbance characterised by *albuminuria and glycosuria* and other metabolic failures. The fractures in this group of cases are usually discovered radiologically rather than *clinically and there may be* some difficulty in separating the syndromes.

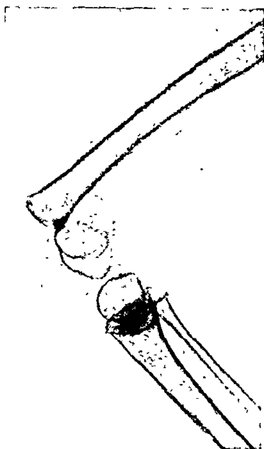


FIG. 91 Scurvy. Spontaneous separation of the lower femoral epiphysis Both lower femoral and lower tibial epiphyses were separated, and soft crepitus was detectable at all four sites.

Endocrine Deficiencies

The *roles* of the various endocrines, as far as bone formation is concerned, being closely inter-related, a complicated picture is formed which is not always easy to unravel. In general, the over-activity of a particular gland, probably working through a secondary gland (for example, the adrenal cortex), is responsible for weakening of the bone structure usually by generalised osteoporosis. Endocrine under-activity such as hypothyroidism and hypopituitarism produces an early closure of the epiphyses and increased bone density. As an exception to this rule *hyper*gonadism produces similar epiphyseal changes.

In hyperpituitarism of the basop
there is an over-production of the ac
inhibits osteoblasts and produces
frequently results in the development of compression fractures of the spine. Hyperplasia of the adrenal cortex will often produce similar

features. In eosinophil hyperpituitarism, which is responsible for acromegaly in adults and gigantism in childhood, there is no associated bone weakness.

In hyperthyroidism there is an osteoporosis which is insufficient to cause fracture, though exceptionally there may be cyst formation in the femur with its consequent risks.

In hypogonadism the pituitary is stimulated. The bone changes are unimportant in the adolescent from the point of view of "spontaneous" fracture, but in the adult female lead to menopausal osteoporosis and contribute to senile osteoporosis in an older age group in the male. The common lesion is a crush fracture of the spine but the weakening of the femoral neck and the frequently associated increased body weight have an important influence on the occurrence of Colles' fracture and fracture of the femoral neck.



FIG. 92. Senile osteoporosis. Collapse of three thoracic vertebral bodies.

In hyperparathyroidism (generalised osteitis fibrosa cystica) there is a withdrawal of calcium from the skeleton and increased secretion of the urine. This negative calcium balance eventually results in marked absorption of bone and cyst formation producing pathological fractures The associated disturbances in other systems and the altered blood chemistry make the diagnosis straightforward, though the early appearance and localisation of the cystic changes to one bone may make the differential diagnosis difficult on a radiological basis.

Secondary hyperparathyroidism occurs in renal insufficiency (renal rickets) and in acidosis nephrocalcinosis.

Osteoporosis from Other Causes

Disuse osteoporosis is seldom important as a cause of "spontaneous" fracture unless carried to extremes by the permanent loss of

function of a limb following hemiplegia or poliomyelitis. More commonly disturbed balance is the responsible factor. Senile osteoporosis is due to a combination of disuse atrophy and hypogonadism to which there may be added vitamin deficiencies. Post-traumatic osteoporosis in its acute form (Sudeck's acute bony atrophy) is probably a vaso-motor disturbance whose reflex pathways



FIG. 93. Osteomyelitis Spontaneous fracture through an area of osteomyelitis in the upper end of the humerus. The drill holes from decompression of the medullary cavity are visible



FIG 94. Spontaneous fracture through a chondromatous cyst of the tibia.

have not yet been worked out. It rarely reaches such a degree that " spontaneous " fracture occurs, but such a limb is more susceptible to injury.

The osteoporosis occurring in osteomyelitis together with the loss of bone due to sequestration may result in a spontaneous fracture, though with penicillin therapy both are so reduced that the accident is becoming rare. *Generally the formation of subperiosteal bone* keeps sufficiently in advance of absorption to prevent the accident occurring.

Syphilis

Syphilitic epiphysitis rarely results in epiphyseal separation though it may occasionally confuse the diagnosis of scurvy. Its more serious influence in "spontaneous" fracture is seen in the tertiary stage where a gummatous osteomyelitis may result in a weakening of the bone sufficient to produce a "spontaneous" fracture; though in general, subperiosteal deposits of new bone tend to keep pace with the areas of rarefaction. Tabes may be indirectly responsible for "spontaneous" fracture when the severity of the injury is not appreciated by the patient or the degeneration in a Charcot's joint renders a condylar fracture of the tibia and femur a possibility.

Local Bone Disease

The more dramatic, more interesting and often more difficult group of "spontaneous" fractures is due to local bone disease, where bone destruction outstrips new bone formation. The discussion of these conditions in full covers the whole field of bony neoplasms and cannot be undertaken here. The conditions responsible may be grouped as follows:

1. *Cysts:* A. *of Bony Origin.*
   - i. Simple adolescent cyst.
   - ii. Fibrous dysplasia {monosteotic. / polyosteotic.
   - iii. Hyperparathyroidism.
   - iv. Chondromas.

   B. *of Blood Forming Tissues.*
   - i. Osteoclastoma.
   - ii. Multiple myeloma.
   - iii. Hæmangioma.
2. *Malignant Bone Tumours:*
   - A. Osteogenic Sarcoma.
   - B. Ewing's Sarcoma.
   - C. Chondrosarcoma.
3. *Secondary Bone Tumours.*
4. *Rare Diseases:*
   - i. Hand-Schüller-Christian (Lipoid granulomatosis).
   - ii. Gaucher's Splenomegaly.
   - iii Hodgkin's Disease.
   - iv. Chloroma (Leukæmias).

The differential diagnosis in the majority of cases is based on radiological examination and is not always straightforward. This is

particularly difficult in the sub-varieties of simple cysts and in the sarcoma of bone. Still further difficulties may arise when the bone pattern has been altered by previous operation. One must therefore have recourse to biopsy. In most cases the apparent risk of interfering with a potentially malignant tumour is much greater than the real risk and it is essential to reach a definite



FIG. 95. Crush fracture of the seventh cervical vertebra in multiple myelomatosis.

conclusion on which to base treatment Thus an osteoclastoma may be confused with a medullary fibrosarcoma or it may be necessary to perform a biopsy of a cyst in Paget's disease to exclude sarcomatous change.

The prognosis and treatment of such cases would be relatively simple were all the conditions strict pathological entities. Unfortunately there are many intermediate varieties such as fibro-myxosarcoma in which there is some doubt as to the degree of malignancy and which may remain as a locally recurrent tumour in the first instance and later take on general malignant characteristics.

Paget's Disease

The increased brittleness of bones affected by Paget's disease frequently results in the occurrence of a fracture which is usually transverse. Fortunately healing is little affected. Occasionally cysts occur, and a fracture may run through them. As these cystic spaces may be the site of sarcomatous change, biopsy may be advisable, and the opportunity may be taken to pack the area with bone chips.

Treatment

In general it can be said that the presence of a pathological origin for a fracture does not in the majority of cases influence the treatment of the fracture as such. The aims of fracture treatment, fixation, anatomical restitution, and early function, remain the same. A notable exception is the primary malignant tumour of bone in which radical surgery is necessary. In the majority of cases union will occur though it may be delayed or callus formation be abnormal in form and amount.



Fig. 96. Pathological fracture through a fibro-myxo-sarcoma of the upper end of the femur.

Where a general condition such as syphilis or vitamin deficiency is responsible, treatment of the underlying condition is obviously necessary. In osteomyelitis routine penicillin treatment will not only clear up the infection but result in union of the fracture.

In senile osteoporosis the osteogenic aid of adequate diet, vitamins C and [illegible]

[illegible] with defective consolidation, under routine treatment are those of Paget's disease and the congenital bony dystrophies.

In hyperparathyroidism, the removal of the parathyroid tumour is obviously the first step in obtaining sound union, though there will be some attempt at callus formation if this is not done. There are

cases in which the affected bone, for example, a rib or the fibula, can be sacrificed without serious consequences, in which radical excision of the tumour and fracture may be practised. Where the tumour is inaccessible to surgery, for example the spine and sacrum, radiotherapy must be employed. In the more common sites of the simple bone tumours around the ends of long bones either radical surgery and packing the cavity with bone chips or radiotherapy may be used, often with almost equal chance of success, the choice being determined by the pathological condition. Radiotherapy is obviously undesirable in the young owing to its interference with bone growth.



Fig. 97. Paget's disease with a pathological fracture

In malignant bone tumours there is only one path to follow, radical excision, which usually involves amputation of the limb through a field of uninvolved tissue at a reasonable distance from the growth. There is little evidence to show that amputation at a great distance from the tumour, for example through the knee or hip for a tumour of the foot, materially alters the average survival rate. However, care must be taken to exclude the presence of secondaries in the lungs and glands, an investigation always open to error in the early stages of dissemination There remains the difficult group of fibrosarcomas of a locally recurrent type and in these cases an invidious choice may lie before the surgeon and patient. Experience suggests that radical treatment should be insisted on.

Secondary malignant tumours are very variable in their osteoclastic powers and often their activity can only be judged by watching their progress A large number of fractures will unite under simple treatment. It is when the fracture fails to unite and where the patient's general condition offers some hope of life continuing for a year or more, that a difficult choice may be placed before one. Occasionally in these conditions amputation may be justified for the

relief of pain and improvement in the patient's general mobility. Radiotherapy may hasten repair by reducing the activity of the malignant cells. It should be given early, as once there is a wide area of bone absorption radiotherapy will not produce union. It is to be noted that radiotherapy also has an inhibiting effect on the growth of new bone and though the patient's pain may be relieved and the expansion of the tumour arrested, absolute non-union with the formation of cortical bone over the medullary cavity may be the end result.



FIG. 98. Spontaneous fracture through a secondary deposit from a carcinoma of the breast. The tumour responded well to stilbœstrol therapy, and the fracture healed rapidly.

In secondary carcinoma of the breast the influence of hormone therapy is unpredictable, but in view of the remarkable response which some breast secondaries show to stilbœstrol or testosterone, treatment is always worth trying. It is interesting to note that the same response may be obtained again in some cases after an interval without treatment during which the growth has recurred. Testosterone propionate is given in doses of 50 milligrammes daily by injection and has been worked up to as much as 200 milligrammes a day. Such massive dosage is of prohibitive cost at present. Stilbœstrol in doses of 20 milligrammes b.d. worked up to 100 milligrammes may be equally effective and has the value of being relatively inexpensive. In secondaries from prostatic carcinoma stilbœstrol may exert a similar effect.

Recently similar effects in sensitive tumours have been produced by total adrenalectomy, which has been followed by the repair of the pathological fracture.

In general the outlook for a pathological fracture is hopeful. Only in the case of secondary malignancy insusceptible to hormone therapy is non-union likely. The uncertainties of pathological fractures demands an optimistic outlook to commence with, and the lines of treatment depart very little in the early stages from those of the ordinary fracture.



Fig. 99. (a) A secondary deposit in the fourth lumbar vertebra from a carcinoma of the breast.



Fig. 99. (b) The inevitable crush fracture which followed Great relief from pain was obtained by radiotherapy.

CHAPTER XII

PLASTER TECHNIQUE

THE age-old use of plaster for the fixation of broken limbs has received a fresh impetus from the aims of modern treatment, with which the accurate fixation afforded by plaster falls more into line. The successful application of plaster demands the use of plaster bandages of constant standards and a speed of handling only given by constant practice. It is essential that where the plaster cannot be applied single-handed a team of assistants familiar with plaster technique be employed, and that they observe a number of simple rules scrupulously.

Material. Plaster of Paris, or gypsum, is calcium sulphate which has been heated and so deprived of its water of crystallisation. Soaking and setting result in the recrystallisation of the material in a solid form. The quality of the plaster is important, as it is obvious that one not deprived of its water content as efficiently as another will not be so good. Again it may be contaminated by admixture with inactive powders. Once a suitable plaster is found, and one becomes familiar with its strength, its setting time, and speed of water absorption, one should not lightly change it. Much of the efficiency of plastering depends on easy familiarity with these points.

Bought plaster bandages differ from home-made ones, for in them the plaster is attached by an adhesive medium to the meshes of the material, while in home-made bandages it is only scattered through the meshes of the material and will shake out. The disadvantages of this are that plaster slabs cannot be made dry, as in doing so the plaster washes out, and that there is usually less plaster at the beginning of the bandage and more at the end, while in bought bandages it is evenly distributed. In the making of small and delicate plasters, such as for the fingers, bought material is an asset, but for most other work home-made material is equally satisfactory. For certain plasters, such as plaster jackets, the rapid setting and high water-retaining qualities of bought material are a disadvantage. Bought bandages are wound more loosely and so soak more rapidly, and the plasters are lighter when finished. Owing to expense they will not be found suitable for large clinics, and the technique discussed in the following chapter is based on the use of home-made bandages, but can always be carried out with bought material.

Home-made plaster bandages must be made of good quality plaster, and the maintenance of uniform tension and weight of plaster in each bandage can only be obtained by practice and experience. It is consequently advisable to have only one or two people making the bandages constantly rather than fresh relays of people. To commence with, they are taught to weigh the bandages after rolling and discard those over or under a certain weight. A little practice and they will be found to roll them so consistently near this weight that weighing may be suspended. Bandages of 4, 6 and 8 inches width will be found the most generally useful, and should be 5 to 6 yards in length.

A 6-yard bandage impregnated with plaster weighs approximately $9\frac{1}{2}$, 14 and 17 ounces for the three respective widths.

Rolling. The bandages used are muslin sized with starch, and of a mesh of 14 to 24 strands to the inch. They must be plucked at the edge to avoid loose threads. Plaster is placed on a flat tray and the bandage settled into this so that a foot length of it lies flat on the plaster-covered floor of the tray. The bandage is then rolled towards one with the right or left hand and the other hand employed (with a flat spatula if desired) in spreading an even layer of plaster on top of the bandage. This portion is then rolled up, and the action repeated again and again till the bandage is completely impregnated. The tightness of the bandage is important for if wound too tightly the centre of the bandage will not be penetrated by water during soaking, while if too loose the plaster falls out and it is awkward to handle when making slabs.

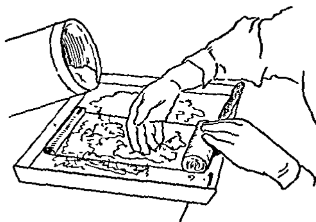


Fig. 100 A convenient method of rolling plaster bandages.

Handling. When used the bandages are dropped evenly into a basin of water which is deep enough to cover the bandage completely. It is ready for removal only when the water has ceased bubbling. If increased speed of setting is desired the water may be hot, and salt (a tablespoon to a quart) may be added. With good plaster this latter expedient is unnecessary. The bandage is then picked up with the hand over either end and squeezed toward the centre till it is devoid of loose water. The free end of the bandage is then undone for a turn and the bandage handed to the surgeon. If a plaster slab is to be made some smooth metal or glass surface is chosen and the appropriate length marked off on it. Holding the loose end of the bandage down to the slab it is unrolled beyond the length required, and then allowed to fall back to the desired length. The fingers are placed on this end and the bandage rolled to the opposite end and the same action repeated. This will demand a change of hands and if there is an assistant available to hold one end of the plaster down it can be done much more rapidly without changing grip. When a suitable thickness is achieved it is smoothed out and lifted off the slab. If a second bandage is to be used it should be placed in the water just before the removal of the first. After several bandages have been soaked the water becomes impregnated with loose plaster and fails to enter the fresh bandages, so fresh water must be used. It is also unwise to



Fig 101 The correct method of wringing the bandage out.

use the same water twice if there has been any delay, as plaster sets in the basin and makes unpleasant loose fragments, which are often picked up by the second bandage.

Once a cast is commenced it should be completed as quickly as possible so that it may set together, and not, as often happens, in separate layers. In large casts this will demand a suitable number of assistants. A forearm plaster may be applied single-handed, a plaster jacket will require one assistant to soak the bandages, remove them as soon as required and hand them to the other assistants, one assistant making plaster slabs and one assistant aiding the surgeon in the application of the jacket.

Setting. This is a chemical process and continues whether the plaster is under water or drying in the air. It is independent of all factors except the quality of the plaster, and takes place in the following stages:

Adsorption of the water of crystallisation together with absorption of water by the bandage and excess water by the plaster.

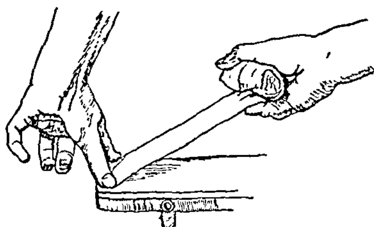


FIG. 102. Making a plaster slab.

Recrystallisation of the calcium sulphate, accompanied by the generation of heat and consolidation of the plaster. This commences in four to seven minutes, and is complete in ten to twenty minutes.

Drying. The excess water absorbed is slowly given off. Excessive water can later soften the set plaster, and it must be dried out as quickly as possible. The length of time necessary for this depends mainly on the thickness of the plaster. The placing of the plaster in an airtight space, *e.g.*, under the bed-clothes, does not encourage it to dry, and it is best treated in a draught of warm dry air, most conveniently obtained under a well-ventilated heat cradle.

Polymerised Plaster. This produces a stronger plaster and there is less loss of plaster from the bandage on soaking it. Its application is therefore cleaner. Some skins are sensitive to the incorporated polymer.

Padded and Non-padded Plaster Casts

Much discussion has arisen as to the advantages and disadvantages of the two methods. Where great argument has arisen truth lies as a rule midway between the two extremes. Many so-called non-padded casts have padding over the pressure points and so are, strictly speaking, padded. Padded casts are only difficult to handle

when excessive and unsuitable padding is used. In this condition they are to be heartily condemned as they do not fit the parts and the padding becomes loose under the plaster, resulting in uneven pressure and pressure sores. The plaster will, as a rule, be unnecessarily large and clumsy, and quite unsuitable for weight bearing. There are many advantages to the unpadded plaster cast, and its use is recommended. It is applied close to the skin, the actual hairs being incorporated and helping in close retention. The plaster can therefore be smaller and more accurately moulded, giving better visual control of position and much better plaster fixation. The absence of padding results in an even pressure on the skin if care is taken to wind the plaster bandage evenly, and the hands are kept moving to avoid pressure points being formed. Plasters should always be held with the flat of the hand and not the fingers, to avoid pressure points. With unpadded plasters pressure sores are less frequent than with padded plasters. Unpadded plasters are more suitable for windowing so that wounds can be observed. Their closer application allows exercise of joints near the fracture with no disturbance of the injured part.

The one great difficulty with them is their inelasticity. In certain areas, such as the wrist and above the ankle, the small amount of fleshy tissue allows little room for expansion before a dangerous pressure on vessels is reached. For this reason circular plasters have been condemned, but it is not the plaster which is at fault, but the judgment of the person using it. To avoid this risk no circular unpadded plaster should be applied to a fracture within twenty-four hours of its occurrence, when further reactionary swelling can be expected. Control of the swelling by even pressure is desirable, and this is best accomplished by the use of a plaster slab for retention, and a circular gauze bandage over it. Later, if desired, a circular plaster bandage can be applied over this In many cases the presence of swelling prevents the application of a plaster suitable for weight bearing and time must elapse with the limb elevated for this to subside At the end of this period a circular bandage may be applied skintight, with no risk at all Similar precautions must be taken after any fresh manipulation of a fracture or any treatment from which reactionary swelling may be anticipated If these precautions are observed unpadded plasters are devoid of danger.

Plaster difficulties. 1. SWELLING. This may occur in spite of precautions and falls into three stages :

(*a*) *No obstruction to the circulation or pain.* This subsides with exercise of the muscles below the plaster and elevation of the part. All fresh plaster cases should be instructed in the immediate use of fingers and toes and the unfixed joints.

(b) *Venous obstruction, with an engorged hand.* Arterial circulation good. There is no pain, but a feeling of tightness. To relieve this the plaster must be split down, the part elevated and exercises encouraged.

(c) *Arterial obstruction.* This should never be allowed to occur. There is gross swelling and cyanosis or pallor of the skin. Capillary circulation is impaired under the nails and there may be loss of arterial pulsation. This condition is always painful in the early stages, and should never be neglected. The cast must be split and spread, the part warmed and elevated, and if no benefit follows in one and a half hours the cast must be removed.

2. Pain. Some aching pain may be expected, but in a well-reduced fracture it is small and relieved by aspirin. Incompletely reduced fractures are frequently more painful. Severe aching pain of a generalised type should raise suspicion of pressure, and demands careful investigation and treatment, as outlined above. It is an important sign not to be neglected and certainly not to be controlled by morphia without investigation.

Local Pain. If the patient can place his finger on a point which is constantly painful, or localises pressure always to a certain spot, he is always right, and removal of the plaster will reveal the commencement of a pressure sore if not a more fully established lesion. To avoid removal a temporary expedient is to cut a window over the point complained of. If the patient cannot localise the pain definitely it may be due to some roughness or to fragments of plaster falling between the plaster and the skin. This can be neglected unless with the passage of time it turns into more definitely localised pain or pressure.

3. Discharge. Unless there has been an open wound discharge always means a moist pressure sore, and demands treatment. Such pressure sores are best treated by fresh air and radiant heat with dry dressings between the applications (see also p. 130).

4. Paresis of muscles. Rarely a walking plaster may press on the peroneal nerve as it winds around the neck of the fibula, and produce foot drop, which is usually not noted till the plaster is removed. It recovers in a variable time with rest, support and faradism to the paralysed muscles.

5. Looseness. This is more uncomfortable for the patient than tightness, and in most cases demands replaster. In certain situations such as the first degree external rotation fracture of the fibula, it does not matter as the important movements of inversion and eversion are controlled by a loose plaster as well as a tight one, and weight bearing does no harm. To avoid frequent replastering the

necessity for the abolition of swelling by early recumbency and elevation of the limb cannot be too seriously stressed.

Plaster Casts and their Construction

The treatment of fractures demands the use of several standard plasters, the construction of which will be outlined here. These plasters are the base of all work, and more complicated plasters are built up on them. Plasters most commonly used are :

Upper limb.
1. Arm plaster.
2. Forearm plaster with fixation of the elbow.
3. Standard forearm plaster.
4. Thoraco-brachial plaster.

Lower limb.
1. Whitman's plaster.
2. Long hip spica.
3. Short hip spica.
4. Long walking plaster. (Ischial bearing.)
5. Knee-fixation plaster.
6. Walking plaster with fixation of the knee.
7. Short walking plaster.

Trunk.
1. Plaster jacket.
2. Plaster bed.

The most adaptable method of construction is the combination of the slab and the circular bandage. Strength is given where strength is required, and the plaster should be lighter in construction than when any uniform thickness of plaster is employed. Given team work the method is quite rapid enough for ordinary purposes. Certain plasters such as the thoraco-brachial plaster are troublesome to apply by this method, and the pattern method may be employed. In the pattern method sheets of plaster impregnated muslin are employed. They may be bought in standard pattern form, or patterns cut from sheets to suit the case. Six to eight pattern sheets are placed together and soaked, and then applied as a unit to the limb to be plastered. They are

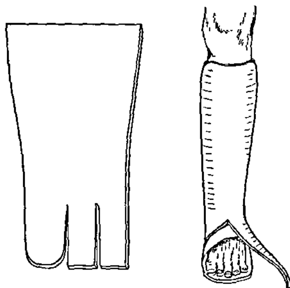


FIG. 103. The "Pattern" method of plastering for the leg

time saving, but unless one is familiar with them apt to be as troublesome in application as any other method. They are heavier than necessary and the sheets of material are not so easy to store for any length of time. Only bought material can be used and the method is therefore expensive. A pattern for a short leg plaster is shown in Fig. 103.

Arm plaster. Used for fractures of the shaft of the humerus. This plaster is most conveniently applied with the patient sitting or standing so that the assistance of gravity may be obtained. A 4-inch bandage is made into a plaster slab equal in length to double the length of the arm. This is placed in



FIG 104. The application of a U-shaped slab in fractures of the humerus. In high fractures the ends of the slabs can be overlapped on the shoulder.

U-shaped fashion along the inside of the arm, around the elbow, and up the outer side. Cuts in the bandage are made just above the forearm, and over the olecranon to mould it around these points. It is then bandaged in position with a gauze bandage, and the arm held in the desired position till set. In cases where swelling is expected it is left so. If swelling is not anticipated it can be reinforced with a circular plaster bandage. The plaster is worn with a sling, and can be steadied with a circular bandage around the arm and thorax, including the sling. If a starch bandage is used for this purpose and passed over the sling the arm is kept very firmly fixed.

Forearm plaster, with fixation of the elbow. This is used for fractures of the elbow region and fractures of both bones of the forearm. Where extension is being used in a fracture of the forearm the plaster can often be applied more satisfactorily in two stages. Where the extension must be maintained while the plaster is setting one stage is used.

(*a*) WITH EXTENSION. The long slab of the forearm plaster is carried up behind the elbow and between the straps of the webbing extension. Plaster is applied overlying the band slightly, but leaving a narrow gap anteriorly through which the extension band is later withdrawn. This gap is then filled in with plaster. (Fig. 349.)

necessity for the abolition of swelling by early recumbency and elevation of the limb cannot be too seriously stressed.

Plaster Casts and their Construction

The treatment of fractures demands the use of several standard plasters, the construction of which will be outlined here. These plasters are the base of all work, and more complicated plasters are built up on them. Plasters most commonly used are :

Upper limb.
1. Arm plaster.
2. Forearm plaster with fixation of the elbow.
3. Standard forearm plaster.
4. Thoraco-brachial plaster.

Lower limb.
1. Whitman's plaster.
2. Long hip spica.
3. Short hip spica.
4. Long walking plaster. (Ischial bearing.)
5. Knee-fixation plaster.
6. Walking plaster with fixation of the knee.
7. Short walking plaster.

Trunk.
1. Plaster jacket.
2. Plaster bed.

The most adaptable method of construction is the combination of the slab and the circular bandage. Strength is given where strength is required, and the plaster should be lighter in construction than when any uniform thickness of plaster is employed. Given team work the method is quite rapid enough for ordinary purposes. Certain plasters such as the thoraco-brachial plaster are troublesome to apply by this method, and the pattern method may be employed. In the pattern method sheets of plaster impregnated muslin are employed. They may be bought in standard pattern form, or patterns cut from sheets to suit the case. Six to eight pattern sheets are placed together and soaked, and then applied as a unit to the limb to be plastered. They are

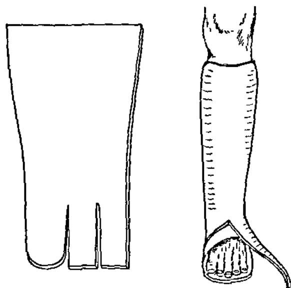


FIG. 103. The "Pattern" method of plastering for the leg.

too tight to commence with. If it becomes loose or has to be cut away it can be replaced with a few turns of strapping or starch bandage. The use of a small piece of iron wire covered in rubber and moulded to the palm, and then incorporated in the plaster is a satisfactory addition as it allows free movements and can be bent tighter as swelling subsides.

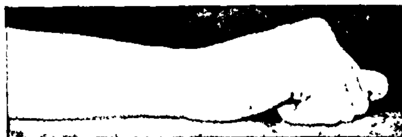


FIG. 106. The resting position of the hand, in which plasters for carpal and metacarpal fractures and foundation plasters for wire finger splints should be applied.

For forearm plasters incorporating finger wires, volar slabs are used, which are best applied with the patient leaning the elbow on the table and allowing the hand to fall back. The wires are placed between the slab and circular turns of bandage. (See Fig. 450.)

To attain the resting position of the wrist the patient is instructed to clench the fist lightly and then lay forearm and knuckles on the table. The dorsal slab is then placed on top of the forearm if the plaster can be applied without extension. This is the most comfortable position in which to plaster any wrist.

Thoraco-brachial plaster. It is perhaps true to state that the elbow cannot be completely immobilised without fixing the shoulder, but it would

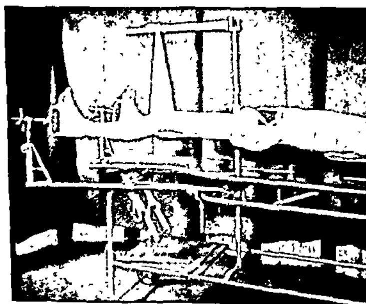


FIG. 107. The padding applied for the application of a Whitman plaster. Note the thin roll in the groin held *in place* by knotting the gauze over the opposite shoulder, and the pad over the anterior superior iliac spine. Note also the slight flexion of the knee.

(b) Without extension. The forearm plaster is applied as usual, but the long slab is continued to the lateral condyle and curved around behind it. When set the extension is removed and a short U-shaped slab placed around the elbow, as in the arm plaster, and bandaged on with a circular bandage while the patient holds the arm at right angles.

(c) For fixation of the elbow alone. A dorsal slab is run down behind the elbow from axilla to wrist, or to the metacarpal heads if pronation and supination are to be avoided. This is cut opposite the elbow for moulding, and covered with short reinforcing strips. The whole may then be bound on

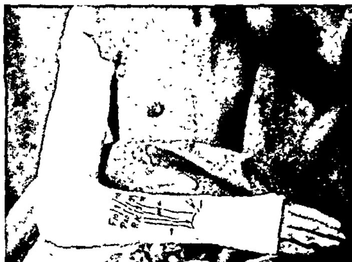


Fig. 105. Immobilising the arm and forearm in fractures of both bones of the forearm. Retention of the forearm fracture has been satisfactory with a short forearm plaster, and over this a U-shaped slab to fix the elbow has been added.

with a circular plaster or gauze bandage. In adults a 6-inch bandage will be found the best and a 4-inch bandage in children.

Where swelling is anticipated the posterior slab should be increased in thickness and gauze only used to bind it on. This can be covered later with a starch or a plaster bandage.

Forearm plaster. This is a standard plaster used with a slight modification for a Colles's fracture or a navicular fracture. A dorsal slab of 6-inch bandage is laid on the dorsum of the mid-pronated hand up to the elbow. It is trimmed or folded back along the line of the metacarpals heads and cut obliquely at the opposite end to allow flexion of the elbow. A vertical cut is made 1½ inches deep parallel with the second metacarpal and the narrow portion folded back over the thumb metacarpal, or cut off. The other side of the plaster is then moulded around the lateral side of the fifth metacarpal and the whole covered with a circular gauze bandage. (Fig. 352.)

Where the fracture is not fresh a circular plaster bandage is used, and then care must be taken that it reaches only to the level of the most proximal portion of the distal line of the palm to allow full flexion of the fingers. Most commonly flexion of the index finger is incomplete, due to excessive plaster. This turn of plaster holding the metacarpals back against the dorsal slab must not be too loose, but as swelling is often maximal in this region it must not be

required, one to soak the bandages, one to make slabs, and one to aid the surgeon in smoothing on the plaster. Some form of pelvic rest must be available, preferably an orthopædic table, but the other substitutes previously described may be used.

PADDING. Several layers of flannel bandage are wound around the chest at the level of the armpits. A felt pad is placed over each anterior superior iliac spine, and held in place by painting the skin with mastisol. A roll of cotton wool 12 inches long and 1 inch in diameter rolled up in a long piece of gauze is placed in the gluteal fold and extending over the ischial tuberosity into the groin. This is held in place by crossing the ends of the gauze over the pad on the anterior spine and tying the ends of the gauze over the opposite shoulder. This padding is then covered by a single layer of calico bandage in the form of a hip spica extending up to the chest bandage.

PLASTERING. Bandages 6 inches in width are most convenient, though 8-inch bandages may be used for the trunk. The plaster is applied in two stages (unless there is a multiplicity of assistants), first the trunk and short hip spica together, and then the leg from thigh to toes. Four plaster bandages are wound on evenly covering the calico bandages, these are then reinforced with plaster slabs. The first is laid vertically down the side of the leg. The second is placed posteriorly and winds from the back over the sacrum and around the great trochanter to the anterior aspect of the thigh. The third slab reverses this passing from the anterior aspect of the trunk over the groin to the back of the thigh. The length of all these slabs is approximately 30 inches. A short vertical reinforcing slab made by cutting a longer slab in two may be laid down the anterior and medial aspect of the thigh if desired. These slabs are covered with three circular bandages and the whole well moulded around the pelvis and upper end of the femur.

The leg is then completed with a long dorsal slab overlying the thigh plaster and continued down to the toes. This is cut on either side of the heel and moulded around it. The sides of the knee are strengthened with two short slabs and the whole covered with three circular bandages. In all fifteen 6-inch plaster bandages will be used, and the total weight of the plaster will be 13 to 15 lbs.

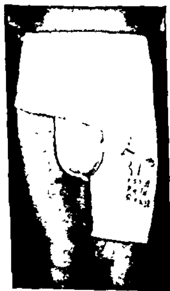


FIG 110. A short walking spica.

Long hip spica. This is used for walking when fixation of the hip is desired, the weight being taken on the ischial tuberosity. It can be used for certain fractures of the femur, both shaft and condyles. It is applied in a similar manner to the Whitman's plaster except that the plaster is not carried so far up the trunk. It is well moulded around the pelvis to obtain good fixation.

Short hip spica. This is used for fixation of the hip without avoidance of weight bearing, such as

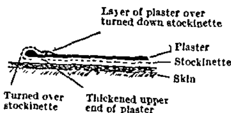


FIG 111. Illustrating the use of stockinette in finishing off the ends of a cylindrical plaster cast.

be an error of judgment to carry this too far. Having immobilised the arm and forearm it is usually only necessary to bind the arm to the side of the chest, either temporarily with bandages or more permanently by plaster (Fig. 275). This is more convenient for transport and for the patient. The application of a thoraco-brachial plaster with the arm in abduction is not lightly to be undertaken, especially if the patient is lying down and under general anæsthesia. In the sitting position it is more satisfactory. In the recumbent patient the back must be supported by a strip of metal along the vertebral column, which can later be withdrawn from the jacket. Some connection between the hand portion and the thorax is desirable in order to strengthen the support of the limb. The plaster is often conveniently applied in two parts. The jacket may be done first while the patient is conscious and the arm subsequently fixed to it. In view of the difficulties in its application the pattern method will be found to save valuable time and is easier than the slab and circular bandage method. The plaster is occasionally necessary in wounds of the shoulder region and of the upper third of the arm, but the majority of fractures affecting the shoulder region can be handled with the arm at the side.

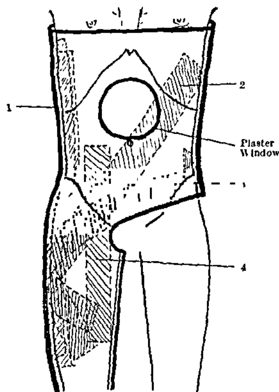


FIG 108. Diagram illustrating the reinforcements used for a Whitman's plaster, and which can be used with modification in any hip spica

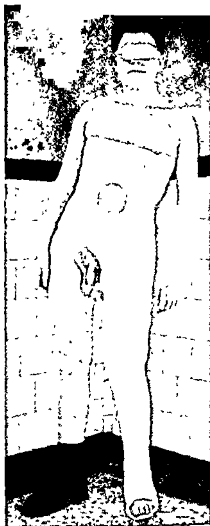


FIG 109 The completed plaster, being used by an ambulatory patient.

Whitman's plaster. To apply this satisfactorily three assistants will be

required, one to soak the bandages, one to make slabs, and one to aid the surgeon in smoothing on the plaster. Some form of pelvic rest must be available, preferably an orthopaedic table, but the other substitutes previously described may be used.

PADDING. Several layers of flannel bandage are wound around the chest at the level of the armpits. A felt pad is placed over each anterior superior iliac spine, and held in place by painting the skin with mastisol. A roll of cotton wool 12 inches long and 1 inch in diameter rolled up in a long piece of gauze is placed in the gluteal fold and extending over the ischial tuberosity into the groin. This is held in place by crossing the ends of the gauze over the pad on the anterior spine and tying the ends of the gauze over the opposite shoulder. This padding is then covered by a single layer of calico bandage in the form of a hip spica extending up to the chest bandage.

PLASTERING. Bandages 6 inches in width are most convenient, though 8-inch bandages may be used for the trunk. The plaster is applied in two stages (unless there is a multiplicity of assistants), first the trunk and short hip spica together, and then the leg from thigh to toes. Four plaster bandages are wound on evenly covering the calico bandages, these are then reinforced with plaster slabs. The first is laid vertically down the side of the leg. The second is placed posteriorly and winds from the back over the sacrum and around the great trochanter to the anterior aspect of the thigh. The third slab reverses this passing from the anterior aspect of the trunk over the groin to the back of the thigh. The length of all these slabs is approximately 30 inches. A short vertical reinforcing slab made by cutting a longer slab in two may be laid down the anterior and medial aspect of the thigh if desired. These slabs are covered with three circular bandages and the whole well moulded around the pelvis and upper end of the femur.

The leg is then completed with a long dorsal slab overlying the thigh plaster and continued down to the toes. This is cut on either side of the heel and moulded around it. The sides of the knee are strengthened with two short slabs and the whole covered with three circular bandages. In all fifteen 6-inch plaster bandages will be used, and the total weight of the plaster will be 13 to 15 lbs.

Long hip spica. This is used for walking when fixation of the hip is desired, the weight being taken on the ischial tuberosity. It can be used for certain fractures of the femur, both shaft and condyles. It is applied in a similar manner to the Whitman's plaster except that the plaster is not carried so far up the trunk. It is well moulded around the pelvis to obtain good fixation.

Short hip spica. This is used for fixation of the hip without avoidance of weight bearing, such as



FIG 110. A short walking spica.

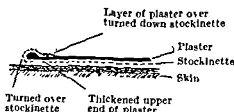


FIG. 111. Illustrating the use of stockinette in finishing off the ends of a cylindrical plaster cast.

may be required in abduction fractures of the neck of the femur. It is applied in a similar manner to the long hip spica, but terminates above the knee. It is very difficult to apply either of these plasters in a satisfactory manner to an exceptionally fat patient. The weight necessary to obtain sufficient strength makes the plaster a handicap rather than an aid.

Long walking plaster. This is used in lesions of the knee region which require fixation and freedom from weight bearing. It is applied by placing the narrow roll of wool previously described in the gluteal fold, and over the ischium and tying it as before. A long plaster slab is then applied from this

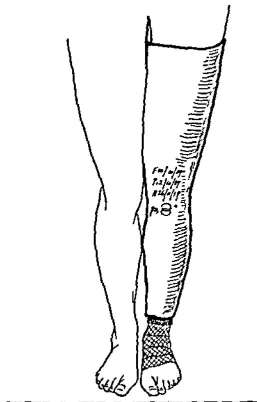


FIG. 112. The knee fixation plaster, as used for a fracture of the patella Note the elastoplast continued below the lower felt pad to prevent swelling of the foot.

to the tips of the toes. It is cut over the ankle and moulded. This is then held in place with the requisite number of circular bandages. Two short slabs are placed on either side of the knee to reinforce it, and covered with further circular bandages. The knee is then held slightly flexed (5° to 10°) and the foot at right angles till the plaster sets. The roll of wool forms a satisfactory upper limit to the plaster and the ischium sits on this. The plaster is trimmed in front to trochanter level. A rubber heel or walking iron may be applied when desired. This can be used to replace a walking calliper if desired.

Knee fixation plaster. This is used for lesions in the region of the knee where weight bearing is harmless but flexion is undesirable, such as a case of fracture of the patella. It is most conveniently applied with the patient on a pelvic rest and the heel on an object at the same level. The use of a layer of stockinette against the skin will make the finishing of the plaster ends easier.

The foot and ankle are strapped in elastoplast to avoid subsequent œdema of the foot. A layer of felt 1½ inches wide is placed over this 3 inches above the malleoli. A dorsal plaster slab is applied extending from the groin level to this, and bound on with a circular bandage. Two 18-inch slabs are placed on either side of the knee and bound on, and circular bandages added till the desired stability is achieved. The stockinette is then pulled back over the ends of the plaster before the final turns and enclosed under them, thus providing a rounded finish.

Short walking plaster. This plaster is the most commonly used leg plaster, as it is the only method of completely relieving the foot of strain. It is important that it should be as light as convenient, and not clumsy, being well moulded around the ankle, and fitting firmly around the knee at the level of



FIG. 113. The method of applying a plaster f[illegible]

as the plaster sets.

the fibula head and the tibial condyles. It must be cut out behind the knee to allow flexion beyond a right angle. The foot must be at right angles to the line of the leg and in the neutral position as far as inversion and eversion are concerned, except in special cases. The plaster must continue to the ends of the toes on the sole, but stop short of the webs of the toes on the dorsum of the foot, so that toe movements are free. The walking iron must not be applied till the plaster has set, to avoid the risk of producing pressure by the metal on the soft plaster.

There are several methods of applying this plaster and it is advisable to familiarise oneself with one and use it alone. These methods are applicable to fractures in which there is moderate union, or to fractures in the ankle region, in which pressure in the long axis of the leg is painless. For fresh fractures, skeletal traction or manipulation and manual retention till the plaster sets, are required.

(*a*) THE STANDING METHOD. The patient lies on the couch and flexes the knee and hip so that he can place the foot against the surgeon's chest. By this means the foot is retained at a right angle, and the hands are left free.

A circular pad of felt 1½ inches wide is bound on over the head of the fibula and at the level of the tibial condyle. A second piece may be put over the dorsum of the toes to prevent rubbing and excessive tightness in plastering.



Fig. 114. The standing method of applying a walking plaster, showing the method of obtaining dorsiflexion against the chest, and the necessary padding of felt.

A 6-inch plaster slab is now run from the upper margin of the felt to the tips of the toes. A cut is made on either side of the ankle and the plaster moulded in. Circular plaster bandages are then applied around the slab including heel and foot, two 6-inch plaster bandages being as a rule sufficient. To plaster the heel the surgeon leans forward, thus pushing on the ball of the great toe, and



Fig. 115. The dorsal slab applied. Commencing the circular bandage.

leaving the heel free. To plaster the toes satisfactorily he must have an assistant to support the heel unless he waits till the plaster has set firmly enough to maintain the ankle at right angles and then trims the toes with a small bandage.

(*b*) THE SITTING METHOD. The technique of padding and plastering are unchanged. The *patient sits on the table* with the operator before him on a low stool. The leg to be plastered is allowed to hang over the edge of the



FIG. 116 The seated method of applying a walking plaster. Dorsiflexion of the foot is maintained by resting it on the knee



FIG. 117. Application of a short leg plaster with the patient lying on his face. The slab shows no tendency to fall away.

table, and dorsiflexion is maintained by resting the toes on the knee of the surgeon. This is a very comfortable and satisfactory method of application.

(*c*) WITH SKELETAL TRACTION the problem of support to the leg does not arise, but dorsiflexion of the foot must be maintained. The plaster includes the wire through the calcaneus, which is removed later if desired. No padding is placed around the wire or pin and the plaster is in direct contact with it. The pin is often retained for a combination of skeletal traction with plaster retention.

(*d*) WHERE SKELETAL TRACTION IS NOT AVAILABLE the limb is best handled under local anæsthesia which enables the patient to co-operate, and makes plastering much more simple than when there is a completely flaccid knee. Manipulative reduction is followed by plastering with the help of an assistant, so that the limb may be maintained in the desired position.

(*e*) THE FACE DOWN METHOD. By laying the patient over on his face,

and then flexing the knee the foot can be easily kept at right angles, and the plaster slab placed on it does not tend to fall off by gravity. It is a position easily maintained by the patient and comfortable for work. It can, of course, only be used for stable limbs (Fig. 117).

Application of a walking heel. This may consist of either : (1) Rubber sole of sponge rubber 1 inch thick and 3 by 6 inches in size. It is held under the sole by a few turns of a plaster bandage. This gives the patient a more natural gait than a walking iron, and is more comfortable, but requires the use of an overshoe to prevent it being worn out. (2) Overshoes with thick sponge rubber heels and soles may be bought and laced over the foot of the

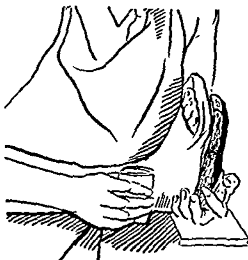


Fig. 118. The application of a sponge rubber sole and heel to a walking plaster.

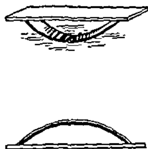


Fig. 119. Rocker sole plate. To a wooden base, a curved metal section, preferably covered with rubber or leather, is fitted.

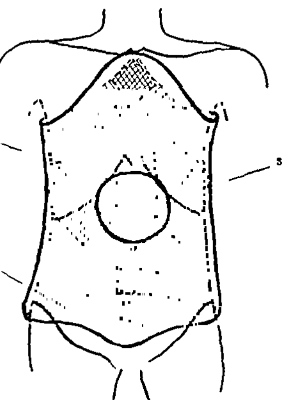
plaster In clinics they will do for several patients. (3) Bohler walking iron. This is applied over the leg plaster so that the heel lies two fingers' breadth below the heel of the plaster and in the line of the tibia and fibula. It is satisfactory but does not give a good gait, as the patient tends to screw his foot out in taking off with the plastered foot. It will stand up to rough usage, and does not require an over-shoe. (Fig. 142.) A modification of the Bohler iron *giving a better gait is the rocker sole (Fig. 119). This consists* of a curved steel band covered in leather which is attached to a sole plate. The sole plate alone is attached to the plaster and it may be used over and over again. A rocking heel and toe gait results.

Freedom of the Toes. There has been considerable discussion as to the advisability of extending the plaster sole to the tips of the toes to provide a platform for the toes. This restricts the flexion exercises of the toes. There is no doubt that all cases of injury to the foot itself should have a platform, owing to the danger of flexion contracture of the toes. This risk is especially marked in cases of pes cavus. On the other hand, patients who are merely lying in bed with the foot fixed as the result of a leg injury can have the plaster discontinued below the ball of the great toe to give adequate exercise to the toes. Similarly when the short walking plaster is used with an overshoe, the

softening of the fore part of the foot to allow normal toe and metatarsal action should be encouraged. In all cases the exercises should be regularly instituted. Where the bed clothes are likely to press on the toes, during transport, the plaster should be continued beyond the toes.

Removal of plasters. The most suitable shears for removing plasters are the Stockholm shears. They should always be introduced in the fleshy side of the limb so as not to produce painful pressure between the bone and the plaster. Forearm plasters should thus be split down the volar aspect. To remove a leg plaster the patient is turned over on his face, and the plaster split over the calf and then over the sole.

The plaster jacket. This is used for fractures or other non-traumatic



IG. 120. Diagrammatic illustration of the reinforcing slabs used in the construction of a plaster jacket. First layer.

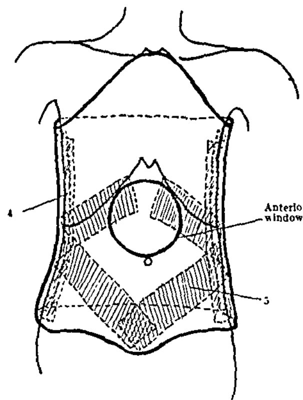


FIG. 121. Second layer.

lesions of the spine. There are various positions in which it may be applied (see Chapter XVII), but the aim of all of them is to produce satisfactory hyper-extension of the spine, and maintain it while allowing the patient freedom of movement. The careful padding of the plaster is necessary to avoid pressure sores. The areas of pressure under such a plaster are, the sternum above, the iliac spines, crest and pubis below, and posteriorly the highest point of the curve of the extended spine, corresponding to the spinal kyphos. Padding of orthopædic felt is placed over these areas. In the method recommended for plastering the dorsal pad is an essential part of the technique and consists of a gamgee pad 15 inches by 4 inches (Fig. 228). Satisfactory padding of the iliac crest may be obtained by painting the skin with mastisol, and running a piece of felt 2 inches wide right around the pelvis, folding the two ends over the pubes anteriorly.

Over these pads a stockinette jacket is applied pinned over the shoulders to keep it smooth. The plaster is then applied. Eight-inch bandages are used for encirclement and 6-inch bandages for reinforcing slabs. Five to six of each will be found necessary. The arrangement of assistants is as for a hip plaster. It is important that all the plaster be applied in a short period (five to ten minutes) so that it may set evenly. A circular layer is first laid carefully over the stockinette, and over this the reinforcing slabs and bandages are applied, the slabs running in the following directions.

1. Horizontally around the anterior and posterior margin of the jacket at the level of the iliac crest. (One long, or two short slabs.)

2. Vertically posteriorly in the midline from the sacrum to the seventh dorsal vertebra. (One.)

3. Obliquely from the top of the sternum around the chest and under the arm to the midline posteriorly. (Two.)

4. Vertically from the trochanter to the axilla on either side. (Two.)

5. Obliquely from the symphysis pubis upwards and around the loins to the midline posteriorly. (Two.)

These slabs are best made from single 6-inch bandages rolled into 30 to 40 inch long slabs and cut in half. They are incorporated under the circular turns which are continued steadily throughout the whole proceeding.

As soon as the plaster has set the patient is placed on a flat bed and after half an hour it will be ready for trimming. The armpits are first cut out so that the arms can be placed comfortably at the sides. Anteriorly the plaster is cut a little below the level of the sternal notch, and in the groins so that full flexion of the legs can occur. Here the tendency is not to cut away sufficient plaster. Extension can be maintained by a plaster which comes only to the level of the anterior superior iliac spines, though usually one removes less than this, leaving a tongue anteriorly to press over the pubes. A circular window is cut anteriorly over the stomach. A longitudinal window is cut posteriorly over the pad covering the lumbar spines. The pad is left in place under this. This is a particularly important spot to relieve pressure.

The application of a plaster jacket is much more satisfactory in a conscious patient. Under anæsthesia one tends to get too great hyper-extension and the patient is difficult to control. Morphia and hyoscine are satisfactory sedatives and usually all that is required. Bought plaster is unsatisfactory to work with; for spinal jackets home-made bandages being the best. After any jacket is applied the patient may vomit during the first twenty-four hours, but this settles down at the end of that time. It is best to get the patient up and about on the first day, as he settles into the jacket more readily. Trimming is usually needed again at the end of twenty-four hours. The plaster should be dried under a heat cradle for the first night, plenty of circulating air being allowed.

After-treatment. This is important and consists of active general bodily exercises, including exercises specially designed for the abdominal muscles. After a fracture of the spine correctly treated the patient should emerge in better physical condition than before the injury.

Plaster beds. These can be made either by applying bandages to and fro over the back of the recumbent patient, or by using sheets of muslin of the size required soaked in plaster cream and laying them layer by layer on the back of the patient. The first method is quite satisfactory, and demands no new technique. The number of assistants required is as for a hip plaster. The patient is laid on his back with appropriate extension, and is covered with a stockinette singlet. Over this bandages are criss-crossed and slabs laid

between them till a reasonably strong shell has been built up. This must be done quickly to obtain uniform setting. The second method demands team work for a satisfactory result. Ten to fourteen sheets of muslin are cut to a size approximately 4 feet 6 inches by 2 feet. Fourteen pounds of plaster are mixed in a deep bucket to a smooth cream. The sheets of muslin are then quickly soaked in this and laid layer by layer on top of the patient, and smoothed into position. If the muslin is slightly moist before it is dipped into the cream it will facilitate its absorption. The plaster is allowed to set, then removed and trimmed. Drying will take two to three days.

Such a plaster bed may or may not include a portion for the head. It is most comfortable if carried down to the mid-thighs, and should have a central portion between the thighs which are thus slightly separated. If the plaster is intended for continuous use a window is cut out over the buttocks and the shell held up on a wooden frame to permit the passage of a bedpan underneath.

FURTHER READING

SCHNEK, F. "The Technique of the Non-padded Plaster Cast." English Translation. Vienna, Wilhelm Maudrich, 1932.

MONRO. "The History of Plaster of Paris in the Treatment of Fractures," *Brit. J. Surg.*, 1935, 23, 257.

GECKLER, E. O. "Plaster of Paris Technique," 1948, London. Balliere Tindall and Cox.

CHAPTER XIII

ANÆSTHESIA

Though intravenous anæsthesia has largely displaced the many alternative anæsthetics, on account of its great advantages, there are still a few cases for which it is unsuitable, and for these there is a wide choice of anæsthetics. Local anæsthesia is unsatisfactory in children, gas does not give sufficient relaxation in many cases, and ether allows too great a relaxation and makes plastering difficult. These and many other points make the choice of a suitable anæsthetic from one of the following not as simple as it may seem at first sight.

1. Local anæsthesia.
2. Regional and block anæsthesia.
3. Spinal anæsthesia.
4. General anæsthesia.
   - (a) *Gas and oxygen.* } These may be combined with
   - (b) *Intravenous anæsthesia.* } a muscular relaxant.
   - (c) *Ethyl chloride.*
   - (d) *Ether and chloroform.*

The factors influencing the choice of the anæsthetic will be: (1) the site and type of fracture, (2) the duration of the anæsthetic required; (3) the degree of relaxation required; (4) the age and mentality of the patient; (5) the presence of other complications; and (6) the anæsthetics available.

Local Anæthesia

Local anæsthesia has many advantages, which are set out briefly in the following paragraphs. (After Bailey and Love.)

1. The fracture may be reduced single-handed.

2. It can be used in patients in whom a general anæsthetic is dangerous.

3. It relieves shock and pain.

4. The patient can co-operate with the surgeon. This may be seen in the application of a plaster jacket, or in setting a fracture of the humerus with the patient sitting up.

5. Reduction can be confirmed by X-rays and if unsatisfactory, the fracture can be reduced again before the local anæsthesia has worn off.

6. The patient does not require any period of recovery.

7. It is particularly useful in compound fractures where the length

of time required for operation is often very great, and the patient's condition unsuitable for a general anæsthetic.

Local anæsthesia has, however, its disadvantages. It cannot be used in children, who will not tolerate the prick of the needle. Further, it is unsuitable for greenstick fractures as there is often insufficient hæmatoma into which the anæsthetic can be introduced and diffuse. In fractures of over forty-eight hours' duration in which some clotting has occurred the same difficulty with diffusion will be met with, and it will not prove satisfactory. The more recent the fracture the more satisfactorily local anæsthesia works. Skin abrasions over the site of the fracture are a

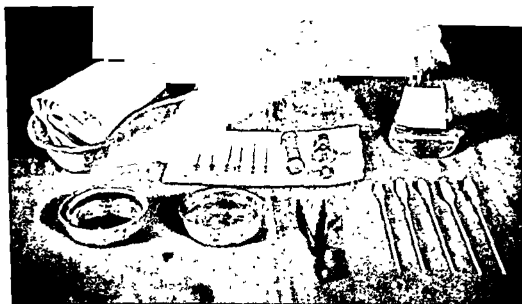


FIG. 122. Tray set up for local anæsthesia.

contra-indication to puncture of the skin, which cannot be adequately sterilised

TECHNIQUE OF LOCAL ANÆSTHESIA. A sterile tray is set up containing the following instruments :

A 10 ml. record syringe, preferably dry sterilised.

Four to six needles. Two fine hypodermic needles for the skin, and larger ones to penetrate into the hæmatomas.

A pair of sterile forceps.

Iodine.

Small swabs, alone or, more conveniently, on sterile swabsticks.

Skin towels.

Two per cent. Novocaine, preferably in small sterile ampoules of 20, 40 and 60 ml., one of which is completely used at a time.

Apart from the handling of the outside of the syringe with the hand the remainder of the manipulations are done with the forceps. No needle is used to penetrate the skin twice. The needle is not withdrawn to fill the syringe, but the syringe is detached.

A careful examination is made, which includes a consideration of the X-ray to decide where the hæmatoma is most easily entered, and with least danger to the soft tissues. This may necessitate several points of entry, *e.g.*, one for a fibula fracture. and two for either end of a comminuted fracture of the tibia in a fracture of the ankle. Having decided this the skin over the appropriate spots is painted with iodine, and skin blebs raised with the hypodermic needle. A larger needle is now inserted, and manipulation of syringe and needle, or more delicately of the needle alone, held in a gauze swab will enable one to determine if one is in contact with the bare fractured surface of the bone, or a part covered with periosteum. When satisfied that the fracture line has been found some 5 ml. of anæsthetic are injected. The syringe is detached and if the hæmatoma has been successfully entered bloodstained local anæsthetic will regurgitate along the needle (Fig. 346). If this is the case the appropriate amount of local anæsthetic is injected and the needle withdrawn. If the hæmatoma has not been entered none, or little, fluid escapes, and it must be sought for again. Quite large amounts of novocaine may be used without danger, up to 60 to 80 ml. Success is shown by the cessation of pain in two to five minutes. The duration of anæsthesia varies from thirty minutes to two hours. In rare or complicated fractures it sometimes fails to relieve the pain, or relieves it only partially.

Regional Anæsthesia

This is suitable for cases in which the injection of local anæsthetics over many sites would be tedious or impossible, and in which the advantages of local anæsthesia are not desired. Its use is limited to the brachial plexus for the upper limb, and the sciatic nerve for the leg.

Brachial plexus anæsthesia. A similar tray is set out as for local anæsthesia. With the patient's head slightly turned to the opposite side a point is selected in the supraclavicular fossa where the subclavian artery can be felt pulsating in the angle between the clavicle and the sternomastoid. The outermost point of this small area is noted, and a spot ½ inch above and ½ inch medial to it chosen. A skin bleb is raised here after painting the skin with iodine. A fresh needle is then entered in a dorso-medial direction, till the patient complains of a stabbing sensation down the arm, indicating that the plexus has been entered. If bone is reached then the needle has been passed too directly back on to the first rib, and must be withdrawn and re-inserted. The plexus lies around and above the artery at a distance from the skin which varies largely with the build and fatness of the individual. In a thin patient

it will only be necessary to enter the needle ½ to ¾ inch, in a fat sthenic individual the plexus may be 2 to 2½ inches deep. If no blood has escaped into the syringe 20 to 30 ml. of novocaine are injected. Loss of sensation in the arm follows at a varying interval sometimes as long as fifteen minutes, and lasts two to three hours. Muscular power is abolished to a variable extent. Combined with a basal narcotic this is an ideal anæsthetic for long operations including skeletal traction on the arm.

RISKS AND COMPLICATIONS. (1) *Perforation of an artery.* This is impossible if due care is exercised and the needle pushed in carefully before the syringe is attached. A hæmothorax has been caused by this.

2. *Perforation of a vein.* This may occur, and merely demands withdrawal of the syringe. It is important not to inject the anæsthetic into the vein.

3. *Paralysis of the phrenic.* This may occur, and is unimportant. There may be cough and shortness of breath.

4. *Involvement of the cervical sympathetic.* This may produce headache, giddiness and a feeling of faintness, and it may be necessary to lay the patient flat. It passes off with no ill-effects.

Sciatic anæsthesia. This may be used for operations on the leg and foot. It is less reliable, and more difficult to achieve than brachial anæsthesia. It is a convenient anæsthetic for the reduction of a fractured calcaneus on one side. If the condition is bilateral a spinal anæsthetic is more suitable.

TECHNIQUE. The most difficult matter is the localisation of the sciatic nerve. This is most readily found in thin patients by rolling it between the fingers and that curved portion of the ischium just above the tuberosity, in the line of the gap between the hamstrings and just above the point where these are covered by the gluteal fold. A skin bleb is raised here, and the needle introduced directly forwards till the nerve is found, and the complaint of pain referred down the leg is made. Twenty to 30 ml. of novocaine are then injected.

In fat patients the nerve is so difficult to find that it is reasonable to use spinal anæsthesia at once. Should it be sought for the same landmarks are used, but the nerve cannot be rolled and must be sought for blindly.

Anæsthesia of a similar duration to brachial anæsthesia will ensue, but it extends only two-thirds up the leg.

Block anæsthesia. This is suitable for lesions of the hand which may be blocked at the wrist, or of the fingers and toes, which may be blocked by injection of the nerves at their bases. It is most commonly employed for the fingers, and the description of the technique personally employed will be given, the more complicated techniques of other block methods being left to text-books on the subject. A tray similar to that previously desc ibed is set up. The skin at the base of the finger is painted with iodine, and two small skin blebs of novocaine are made on either side of the knuckle posteriorly. A slightly longer needle is then used, and is made to penetrate forward on the side of the phalanx till it lies just below the palmar skin. By infiltrating as the needle is advanced and withdrawn, the anterior aspect and the digital nerves on the antero-lateral aspect of the phalanx can be anæsthetised. The needle only requires to be pushed laterally toward the opposite bleb and the dorsum of the finger infiltrated to have complete anæsthesia of the finger. This method by utilising an approach through the finer skin on the dorsum of the hand is easier and much more comfortable for the patient.

Spinal anæsthesia. This is particularly useful for cases in which both legs have been injured, such as bilateral fractures of the os

1. THE BED. For the patient's comfort and nursing convenience it is important that this should be satisfactory. Most of the advantages of complicated beds can be obtained more cheaply and equally satisfactorily by additions to an ordinary iron bedstead. Such a bed should have a firm iron frame and wire mattress on which fracture boards can be placed. A convenient height for this mattress is 26 inches from floor to wire. The stuffed mattress should be firm and even, and for this horsehair mattresses cannot be bettered.

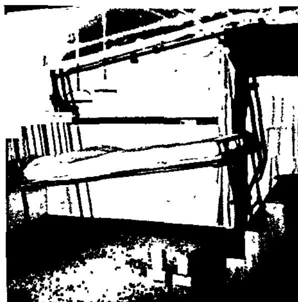


FIG. 123. Suitable fracture bed arranged with hand pulley, iron Balkan beams (now only occasionally required), and fracture boards. The end of the bed is elevated on wooden steps, the most suitable assistance for high elevation. For low elevation the blocks on the floor may be used

If a divided mattress is available, with a removable central portion, the use of the bedpan will be facilitated. All beds must have an attachment at the back so that the overhanging pulley may be provided for the patient to elevate himself. In place of this a fairly low Balkan beam may be used which has the advantage of allowing the patient to run hand over hand down it and so flex himself to any degree, and thus obtain valuable exercise for the spinal and other muscles

2. BLOCKS. The elevation of the end of the bed to obtain counter-traction from the body weight is constantly required and may be made on blocks of varying height (6, 9, 12 and 15 inches are useful heights), adjusted to the pull required and the weight of the patient, or on a wooden step ladder on which both legs of the bed are placed. This is the more stable arrangement when the foot of the bed is elevated over one foot.

3. ORTHOPÆDIC TABLE. The possession of an orthopædic table of the Hawley or Putti type is almost a necessity if much work on the hip is to be done, but for plasters without extension a pelvic rest with a small stool to go under the shoulders can be used. The feet in this case are supported by assistants. A very convenient pelvic rest is made for attachment to the Böhler leg traction splint, and this gives almost all the conveniences of an orthopædic table including leg traction, at considerably less cost (Fig. 130).

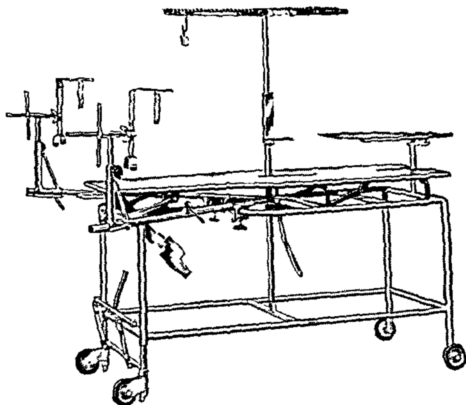


FIG. 124. Hawley table.

4. COUNTER-TRACTION BANDS. For many methods of reduction, and the retention of a fracture while plaster is being applied, counter-traction is necessary, and this is best provided by webbing bands attached to a hook in the wall some 6 inches above the table height. The use of such a band is almost a necessity in forearm fractures. (See Chapter XXII for illustrations of its use.)

5. KIRSCHNER WIRE APPARATUS. This consists of a drill, of which there are many types, both hand and electric, and some apparatus for tautening the wire and maintaining it stretched. There are many stirrups (or tractors) designed for this purpose, the more convenient consisting of tractor and strainer combined. The simplest form consists of a metal horseshoe with two clamping screws at either end, and adapted to take a strainer. With one screw

clamped down the wire is tightened and is held taut by tightening the second screw. Strainer and excess wire are then removed. For cutting Kirschner wires a specially strong type of wire cutter is required.

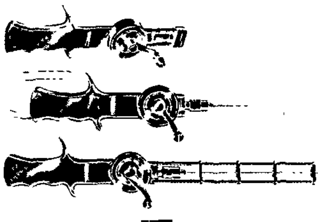


FIG. 125. An effective variety of Kirschner wire drill.

6. STEINMANN'S PINS These are stainless steel rods of varying diameter from 2 to 4 millimetres. One end is sharply pointed and the other squared for the introducing handle. They may be hammered through bones like the calcaneus, or drilled through as though using a bradawl by the introducer. We have found the most satisfactory method is to drill the bone first with a small wood twist drill of smaller diameter, and then insert the pin through this hole. It gives one accurate control over the direction of the pin and is comfortable for the patient The pins are held in stirrups which are attached to either end by a collar and screw so that the stirrup can rotate without rotating the pin. A rotating pin is a common cause of sepsis in the pin-hole.



FIG. 126. A Kirschner wire strainer and tractor combined.

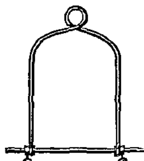


FIG. 127. Steinmann's pin and stirrup.



FIG. 128. Steinmann's pin and introducer

7. BOHLER'S SCREW TRACTION APPARATUS FOR THE LEG This consists of a rectangular tubular steel frame with uprights carrying cross-bars. One bar is placed under the flexed knee. The other bar carries a screw

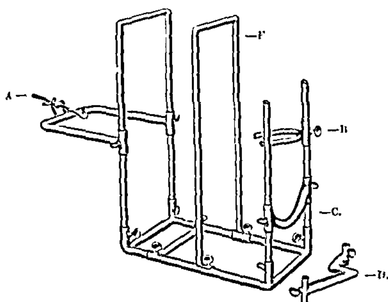


Fig. 129. The Böhler leg extension frame. A. Extension screw. B. Pelvic support, used only with additional leg piece. C. Bar for support under the knee. D. Another variety of bent knee rest. F. Upright support used in calcaneal fractures. (See Fig. 597.)

with a wing nut, which has a hook attached, and to this the stirrup of a Steinmann's pin is attached by copper wire, with a spring balance intervening. By tightening the wing nut an increasing pull can be put on the leg and registered on the spring balance. A third detachable upright is important as it can be used to support the lower third of the leg which is hung from it by a bandage. This frame can be

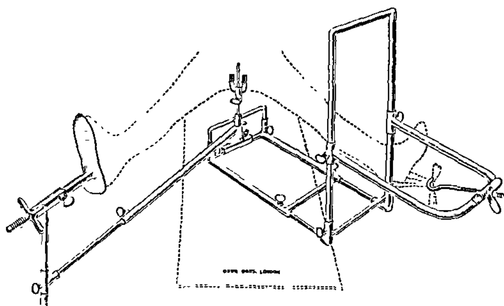


Fig 130. Showing the use of a pelvic support and leg extension piece added to the Bohler leg extension frame, which makes it suitable for hip plasters.

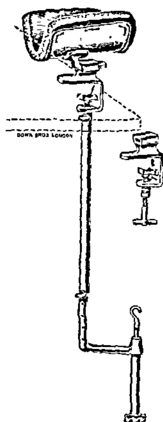


Fig. 131. Watson-Jones' Extension. Apparatus for the leg, which offsets the effect of gravity. (*Down Bros*)

combined with a pelvic rest and adjustable foot piece, and so be used for traction on the straight leg. It can be used also for forearm and arm fractures. This piece of apparatus, with the addition of a pelvic rest piece, can replace a Hawley table, or be used instead of an arm traction frame. It can thus be a very useful and economical addition to one's apparatus. Watson Jones' apparatus is designed to avoid the action of gravity traction being applied to the leg in the dependent position (Fig. 131). The apparatus is convenient for the leg, but not so adaptable.

8. Böhler's screw traction apparatus for the arm. This is occasionally useful, but the apparatus described above can be used in place of it.

9. Braun's splint. This skeleton splint is a modification of Pettit's trough leg splint, and is a very convenient and adaptable splint for most fractures below the pelvis. It consists of a rigid iron frame which sits on the mattress of the bed, and from this two parallel iron bars slope up to support the thigh, and then run parallel to the bed to support the calf and leg. Over the foot runs a steel arch, and to this are attached pulleys in the line of the femur. The

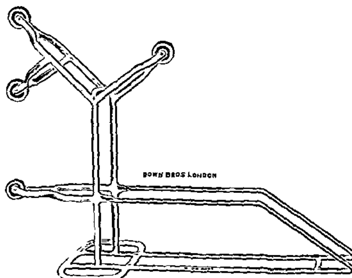


Fig. 132. Bohler's modification of Braun's splint.

two leg bars are prolonged, and end in a pulley on the level of the leg. By bandaging the parallel bars a trough for the leg may be made. The thigh portion should be bandaged firmly to make a flat surface, and the leg portion more loosely to allow the calf to sag into it.

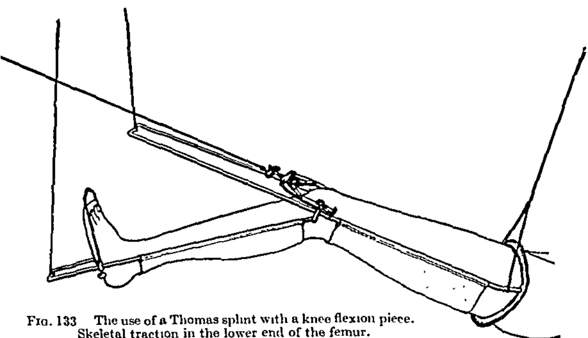


FIG. 133 The use of a Thomas splint with a knee flexion piece. Skeletal traction in the lower end of the femur.

The bandage should stop before the heel to prevent pressure sores. The foot is conveniently supported by stockinette bandaged over mastisol, or by strapping and a spreader, attached to the bar of the arch, or pulled on lightly by a 1 lb. weight passing over the upper pulley. This is essential to steady the foot, and prevent foot drop.

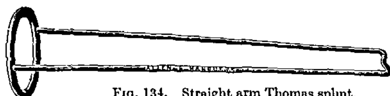


FIG. 134. Straight arm Thomas splint.

10. THOMAS SPLINT. This is another skeleton splint of an adaptable nature particularly if it has a knee-flexion attachment. The leg Thomas consists of a padded leather ring attached at the angle of the groin to two iron bars which run, narrowing towards one another, till joined transversely, at a variable distance from the ring. In the arm splint the leather ring lies at right angles to the line of the side bars, and is hinged on them. In the leg splint it is placed obliquely to adapt it to the angle of the groin. This is a most useful first-aid splint, and is used where it is desirable to treat the leg with the knee extended. With the knee-flexion piece it can be used in

the same manner as the Braun's splint, or it may be bent at the level of the knee to obtain knee flexion. Its chief disadvantages are the discomfort of the ring, particularly at the shoulder, and the fact that it needs some support, such as a Balkan frame to carry it. When the splint is slung, however, it responds to the patient's movements in

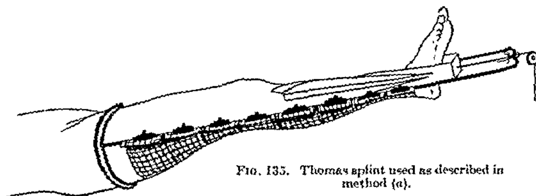


Fig. 135. Thomas splint used as described in method (*a*).

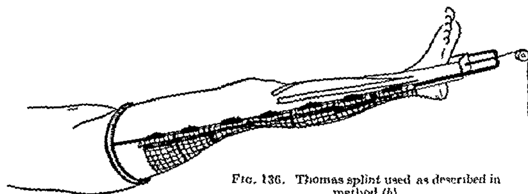


Fig. 136. Thomas splint used as described in method (*b*).

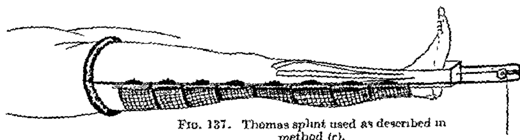


Fig. 137. Thomas splint used as described in method (*c*).

the bed, without disturbing the fracture. It therefore provides a degree of comfort which no splint firmly attached to the bed can do, and this alone justifies its use in any long term case, in preference to the Braun's frame. There are several methods of application of the splint.

(*a*) The strapping or skeletal traction is tied to the splint and both pulled on together. This releases the ring from pressure, and the bed must be elevated for counter traction.

(*b*) The splint may be used as a support only, and the extension

be taken from the skin or skeletal traction apparatus. This is the most useful and satisfactory method.

(c) The extension may be made to run through a pulley attached to the splint so that there is an equal counter pressure on the ring of the splint. If this is done the bed need not be elevated.

11. ABDUCTION SPLINTS. A great variety of these have been produced. The greatest difficulty with this splint is maintaining it in position. This is attained by the use of straps or bandages, and these need constant attention to prevent dropping of the splint, which then drags on the arm, and may produce the deformity it is

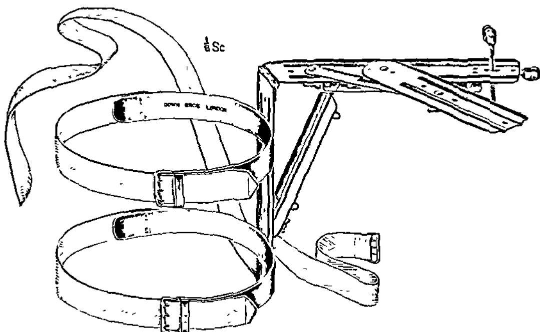


FIG. 138. Bohler's arm abduction splint.

desired to correct. Their correct application, so that the hand is in front of the face and the arm at an angle of 45° to the frontal plane, to relax the pectorals is also not easy to attain. The splints used fall into three types : (1) those used for support only ; (2) those used for support together with continuous traction on the arm, provided by a separate spring ; (3) those in which the elasticity of the splint provides some traction on the arm.

An effective and useful splint of the combined first and third types may be made from 3 or 4-inch Cramer wire suitably bent and wired together with copper wire (see Fig. 139). The splint is padded carefully with tow or wool. It has the advantage of being cheap, light, and readily adaptable to varying bodily habitus. It is applied by bandaging the two body pieces firmly to the chest, while an assistant holds the splint firmly up into the axilla. Over these an oblique bandage is placed, running over the opposite

shoulder and around the bottom of the vertical bar of the splint, around which one twist is taken with every turn of the bandage to lock it. These bandages need re-application in two to three days when they have stretched. If they are now re-applied and covered with two starch bandages the splint may be made firm for



Fig. 139 Abduction splint made of Cramer wire strips wired together with copper wire and padded. A cheap and adaptable splint.

two to three weeks It is very difficult to apply an abduction splint to an unconscious patient, and it is advisable to apply the splint before manipulations are commenced in cases in which a general anæsthetic is to be used.

12 Cramer wire. This skeleton wire, consisting of strong wire uprights with lighter wire cross-bars resembling a ladder, is very



Fig. 140. Cramer's wire ladder splinting.

convenient material for making temporary splints. The most comfortable of back splints may be made by wiring two lengths together to give rigidity and then moulding them to the shape of the posterior aspect of the knee, calf and heel, and padding them. This makes an ideal resting splint for sprains, lacerations and cases such as fractured patellas awaiting operation. Similar *short splints for the hand, elbow and forearm can readily* be made.

13. Finger wires. These consist of light iron wires bent as shown, and approximately 10 inches long with $1\frac{1}{2}$-inch side pieces. They can be incorporated in a forearm plaster when traction is required on a finger, and are then used unpadded, being covered with strapping after incorporation in the plaster. Where it is only

required to rest the finger it is sufficient to use a padded splint curved to fit the flexed finger and palm, and bound on with a gauze bandage covered with a starch bandage (Fig. 48).

14. FELT is a very useful padding material. That with a sticky surface has its uses, but mastisol painted on the skin will enable plain felt to be put to a similar use. It is used to cover pressure points in such plasters as that for a fractured spine, or to make a comfortable bearing surface in a walking plaster.

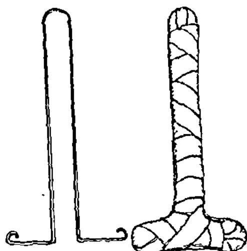


FIG. 141. Wire finger splint, unpadded and padded. Compare Fig. 48.

15. ROCKER SOLES. These consist of a simple wooden or iron section of a small circle attached usually to a wooden base plate. They are made in variable sizes. For an adult the base measures 7 inches by 3 inches and the attached curved portion, 5 inches with a maximum depth of 1¼ inches. They are cheap, easily made, and permit a more normal gait, avoiding the screwing action frequently seen with the walking iron (Fig. 119).

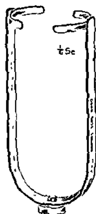


FIG 142. Walking iron with attached rubber stud.

WALKING IRONS. These consist of a bent light metal bar to which a rubber heel is attached. They are bent in the shape of a U and incorporated in a leg plaster to bear the weight. They are best applied by a separate plaster bandage after the leg plaster has set, to avoid the metal making pressure marks in the fresh plaster. They are applied so that the centre of the bar is two fingers' breadth below the plaster on the heel, and in line with the tibia and fibula.

16. SPONGE RUBBER. Sponge rubber pads, 1 inch thick and cut to a size of 3 by 6 inches, may be attached to the leg plaster by a few turns of bandage over the foot. They have the advantage of allowing a more natural gait, but they must be protected by an overshoe of some description.

17. MASTISOL. (Gum mastic 40 parts, Ol. Ricini 1·2 parts, benzine 100 parts.) This varnish provides a sticky skin surface which improves any grip on the skin, such as required in the reduction of Colles's fractures, or in the application of plaster for continuous skin traction. Here it is advisable to paint the skin once before the application of the strapping, and then paint over the

strapping when it is applied and cover the whole with a few turns of gauze bandage.

18. UNNA'S PASTE. (Zinc oxide 150 grams, gelatin 150 grams, glycerine 350 grams, water 350 ml. Soak the gelatin in the water till soft, add the glycerine, heat and adjust the weight with water to 850 grams. Sift in the zinc oxide and stir till even. Allow to set in a tray, and cut into blocks to be melted for use.) This is used in the treatment of varicose veins, but it can be used for skin traction or making elastic stockings. It is applied with a large brush and painted warm on the skin. A layer of gauze bandage is then wound evenly over this, and another coat of paste applied.



FIG. 143. Materials for the application of Unna's paste stockings.

This is repeated till three layers are evenly applied. The application is finished by wiping the surface with 6 per cent. formalin in spirit and covering the resultant moist surface with a fine layer of cellulose wool. " Viscopaste " bandages are a convenient proprietary preparation, from which elastic stockings may be made. Elastoplast serves the same purpose, but is more expensive.

19. STOCKINETTE. This is a useful material for obtaining a smooth lining to plasters such as spinal jackets In limb plasters, by pulling it down over the end of a moist plaster satisfactory smooth, rounded ends may be obtained (see Fig 111).

20. STRAPPING. The ordinary zinc oxide strapping sticks better if the skin is painted with mastisol first. Where close application with increased flexibility is desired, *e.g.*, in supporting a joint, strapping with a single or double elastic weave (elastoplast) is more satisfactory, though there are certain situations where this increased elasticity is a disadvantage The single stretch strapping is the more generally useful.

21. Wooden spatulas. These are useful in holding apart the ends of ready-made strapping extensions and enable the strapping to be applied with the minimum of disturbance. Wooden spreaders

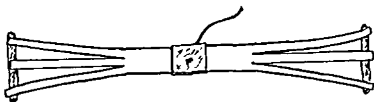


Fig. 144. Skin extension made from ordinary strapping, torn ready for use. Central spreader attached, and the ends held apart by attachment to tongue spatulas.

are necessary to obtain an even pull on the plaster and to prevent pressure on bony points, such as the malleoli.

22. Cord, hooks and weights are essential. Two-pound weights will be found most useful. Hooks are necessary as an attachment to the stirrup, and a second hook on which the weights are hung facilitates adjustment.

23. A spring balance placed between the screw of the screw traction apparatus and the stirrup will record the pull applied. A balance registering to 60 lbs. is most useful. Smaller balances may be used for registering the traction on the arm in an abduction splint.

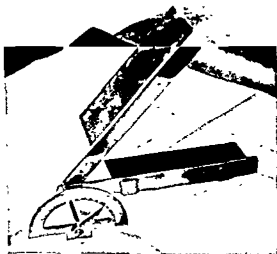


Fig. 145. A goniometer particularly useful for measuring elbow movements.

24. Starch bandages. These consist of ordinary gauze impregnated with starch. They are boiled for a few minutes and then placed in cold water As soon as they are cool they are applied. They contract slightly in setting and so obtain a firm grip, accentuated by the fact that each layer sticks to the next. They are useful to maintain splints and bandages in position over a long period.

25. Goniometer. Some simple apparatus for keeping a check on the movement possible at the elbow is essential to accurate observation of that joint. The one illustrated is of personal design, the flat surfaces lying along the surfaces of the ulna and the triceps While giving a few degrees variation, depending on how firmly it is pressed into the muscles, it gives a more consistent accuracy than

other instruments. It is adaptable to other joints such as the knee and hip.

26. COPPER WIRE. This is necessary for binding Cramer wire splints together and for connecting up parts of the extension apparatus, especially if a spring balance is not used.



FIG. 146. The Phelps-Gocht osteoclast.

27. OSTEOCLAST. This is a necessity for breaking down firmly united fractures, and is useful for the reduction of some fractures. The Phelps-Gocht apparatus is shown ; or the Thomas wrench may be used. It is a luxury only needed in a busy clinic.

28. CALCANEAL CLAMP. This is necessary for the complete reduction of a fracture of the calcaneus with broadening of the bone. It can also be adapted for compressing the upper end of the tibia, or the lower end of the femur if special pads are used. It is a strongly made clamp tightening the jaws evenly, over a bar on which the distances between the clamp faces are measured. In use the convex pad is applied to the outer aspect of the calcaneus, and the reniform pad to the inner aspect so that it clears the sustentaculum tali.

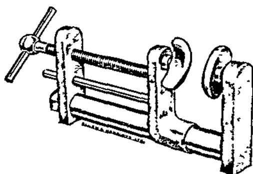


FIG 147 The Bohler redresseur, or calcaneal compression clamp.

29. INDELIBLE PENCILS. These are the most suitable for recording on the plaster the dates of fracture, reduction, and approximate removal of the plaster, together with a diagram of the fracture.

31. PLASTER INSTRUMENTS The most generally useful instruments are ·

Stockholm plaster shears.
Plaster scissors.
Plaster case openers
Round-pointed scissors.
Old scalpels or ankle knives.

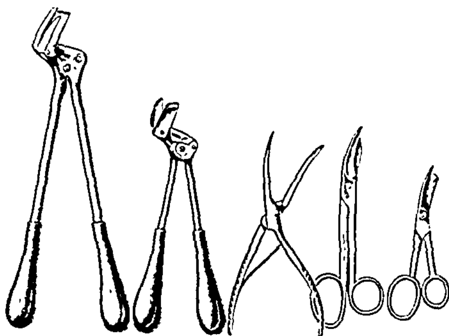


Fig. 148. Stockholm plaster shears, large and small, plaster case openers, plaster scissors, probe point scissors.

32. Knee exercise bar. This consists of an adjustable transverse bar whose height can be varied. It can be placed on the bed so that the recumbent patient may bend his knee over it and so exercise his quadriceps. It can be used very early in treatment and aids materially in the maintenance of movement in the knee.

33 Arm splint for traction with the bent elbow. This simple apparatus consists of a vertical upright standing on a wooden base to which is attached at the height of the top of the wire mattress a strong lateral bar. This bar is laid between the wire mattress and the fracture board, where it is well gripped by the patient's weight, but allows free variation of its position so that the pull can take place at any angle to the central line of the bed. The vertical upright, thus firmly held, is slotted above this level, and through this slot runs a clamping screw with a wooden block on either side. To one block is attached a pulley, to the other a hinged board 4½ inches wide, which stretches to the approximate level of the centre of the bed, where it tapers off. On the top of the upright, at a height of 5 feet from the floor, is another cross-beam which projects 2 feet on the bed side and 1 foot on the opposite side. To it

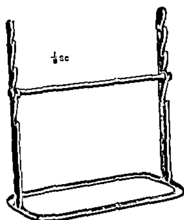


Fig. 149. Knee exercise bar.

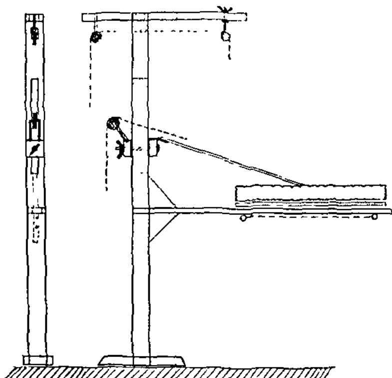


Fig. 150. Diagram of the apparatus described for traction on the arm with the elbow bent. Compare Figs. 151, 152.



Fig. [illegible]

top of the mattress.

pulleys are attached, the one over the bed moving in a groove in a similar manner to the armrest piece. The cords for traction are run over the lower pulley for the arm and over the upper two pulleys for the forearm. It will be seen that any position of the arm in relation to the trunk can be obtained, as the apparatus is movable in both the horizontal and vertical planes, and that the angle of the elbow can



Fig. 152. Details of the apparatus shown in the previous figure. The strapping extension on the forearm requires a pull of 4 lb. to maintain it vertical. The arm lies along the sloping support board, and is undergoing skeletal traction through a pin in the olecranon, the average pull required being between 6 and 10 lb.

be varied very considerably by adjusting the angle of the arm piece, and the position of the upper pulley. The apparatus is simply made by any carpenter, is inexpensive, effective, and does not occupy valuable space around a bed, nor look untidy.

34. Plaster. *This has been fully described.*

FURTHER READING

Sinclair, M. "The Thomas Splint and its Modifications." Oxford Medical Publications, 1927.

Nangle, E. J. "Instruments and Apparatus in Orthopædic Surgery," 1951, Blackwell, Oxford.

CHAPTER XV

FRACTURES OF THE SKULL

(Mr. T. G. I. James, M.Ch., B.Sc., F.R.C.S.)

Surgical anatomy

From the point of view of violence applied to the skull it must be regarded as an elastic sphere. The base of the skull consists of dense and irregularly thickened bone, which is weakened by numerous foramina and fissures, but is made more rigid by the support of the bones of the face anteriorly, while posteriorly it receives strong support from the spinal column by way of the occipital condyles.

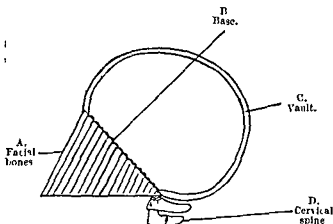


Fig 153 Diagram to illustrate the basic mechanical construction of the skull.

The vault behaves as a sphere in compression injuries to all points on its circumference, but the inelastic base is incapable of reacting evenly to the strain so that internal stresses are set up, which frequently fracture the base or junction of base and vault, such cracks running complicated paths through fissures and foramina. The bone of the vault consists of two compact layers, the inner and outer tables, united by cancellous bone, the diploë. The outer table is stronger than the inner, which is grooved by the meningeal vessels, and so in perforating injuries the inner table is often most damaged. The mechanical forces generated by a bullet passing out of the skull after perforating it are such that at the point of exit the outer table is more damaged. In other words, the outer table lends support to the inner table, which is cleanly perforated, and the unsupported outer table is shattered, the reverse being the case at the point of entry.

General considerations. Fractures of the skull derive much of their importance and interest from the associated damage to the brain and other structures inside the skull. It must be remembered

that any form of brain damage can co-exist with any type of skull fracture, though they are usually relative, the more severe the fracture, the more severe is the brain injury. In 80 per cent. of cases of severe brain damage there is a fracture of the skull.

Discussion of fractures of the skull must therefore differ from that of fractures elsewhere in that consideration of soft tissue injury must often overshadow the bony injury. Fractured skulls must be considered in the light of the trauma to the brain, and their treatment must embrace the treatment of the cerebral injury. In order to regiment one's thoughts the types of fracture must be grouped and the possible brain injuries discussed as separate entities, though it must always be borne in mind that they run into one another, as may be seen in Fig. 154, which represents the common sequence of events.

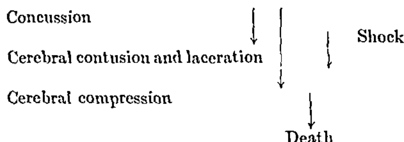


FIG. 154 Injuries to the brain which may occur with or without fracture of the skull.

Bony Lesions in Fractures of the Skull

Type of violence. (1) DIRECT. (*a*) Puncture wound with sharp instrument. Compound depressed fracture. Most frequent through nose or orbit. Perforation of vault less common.

(*b*) Large force on limited area, *e.g.*, hammer blow, bullet. Produces a depressed fracture, often with comminution.

(*c*) Large force on large area. Blows with blunt weapons, or falls in which the skull strikes a hard surface. Produces fissure fractures of the vault which may also involve the base.

(*d*) Glancing blows with a sharp edge, *e.g.*, a sword, are rare, but may produce elevated fractures. The tendency of the spherical skull to glance off a blow protects it from much direct violence.

2. INDIRECT. Falls on the buttocks, in which the force is transmitted up the spine to the occipital bone, fracturing the skull base, and blows on the point of the chin, which may fracture the base through the condyle of the jaw.

Usually these lesions and their associated damage are grouped as follows ·

1. *Vault.* Fractures may be fissured, stellate, comminuted,

depressed or elevated, simple or compound. Readily seen in X-rays

2. *Base.* Fractures usually fissured. Not easy to see in the X-ray without special views, *e.g.*, Johnson's for those in the anterior fossa. Frequently compound because fracture may traverse air-containing sinuses.

Fractures of the Vault

Mechanism. Any blow on the skull of a severity sufficient to deform the skull at the point struck produces a series of changes in the skull and its contents, which varies in magnitude. Blows

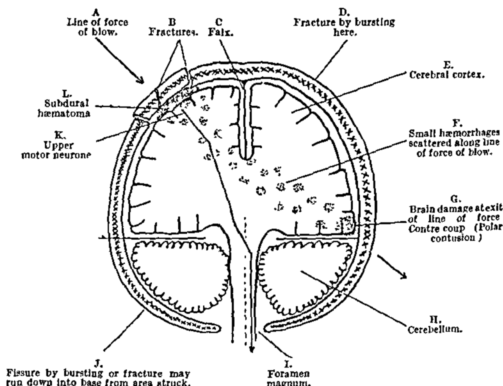


FIG. 155 Illustrating the various possible effects following a blow on the skull.

restricted to small areas tend to damage the scalp tissues as well and therefore are often compound. They produce severe damage at the point struck, *i.e.*, depression with irradiating cracks. The inner table, as mentioned, is more severely damaged, being the weaker, more brittle, and grooved by the meningeal arteries. Blows over larger areas produce flattening at the point struck, with narrowing of the skull along the diameter represented by the direction of the force, and a corresponding increase in diameter at right angles to this. If the force distorts the skull beyond its natural elasticity, fractures will occur. The brain may undergo injury at the point

of impact, and is damaged by internal stresses to a varying degree along the line of force of the blow, and most severely damaged at the point of exit of the line of force from the brain, where the brain is thrown against the opposite side of the skull (" Contre coup ").



FIG. 156 Fine fissure fractures of the occipital bone running into the foramen magnum, following a fall on the back of the skull.

The skull itself tends to fracture at the point of impact from the compression, and this may take the form of a fissure, though it would be more characteristically shown by a depressed fracture with some irradiating fissures. The bursting strain which occurs in the skull in a plane at right angles to that of compression (see

Fig. 155) is probably a very rare cause of fracture, and more commonly the fracture is seen to run in the same direction as the line of force. This is due to the fact that the vault is not a true sphere, but is only two-thirds of one, with a firm and rigid base (Fig. 153). Fractures from local deformation are often associated with those due to general distortion and fracture patterns are very numerous because the skull consists of many comparatively thin areas enclosed by strong buttresses.

Fractures of the Base

Mechanism. This may be

1. Perforation, *e g.*, a foreign body pushed through the orbital plate or roof of the nose.
2. Irradiation from a fracture of the vault.
3. Bursting fracture, from general distortion of the skull.
4. By forces transmitted along the spine to the occipital condyles, a common mode of fracture of the base in falls.
5. Indirect violence applied to the point of the jaw or face may be transmitted to the skull base.

The areas of the base most liable to damage are the cribriform plate, the orbital plate, the body of the sphenoid, the petrous bone, and the thin areas of the cerebellar fossæ. The dangers arise due to the fissures communicating with potentially infected cavities, such as the ear, nose and sinuses.

Mode of Brain Damage

1. PENETRATING INJURIES (Fig. 157). The penetration of a bullet or a fragment of shrapnel produces an explosive effect inside the skull and damage scattered along the track. Foreign bodies, both bony and metallic, may be distributed among the bruised tissues and vascular damage may be severe.

2. LOCAL DEFORMATION (Fig. 158). The degree of damage permitted by this is dependent on the elasticity of the skull. In the adult 70 per cent. of cases of severe brain injury will show fractures of the skull, and fractures will be found in 90 per cent. of autopsies for brain injuries Local deformation produces local brain damage. It is perhaps most important as a cause of injury to the meningeal vessels.

3. MECHANICAL CAUSES. The brain having inertia and not occupying fully the skull cavity, is liable to injuries from acceleration and deceleration. Although lying in a fluid bath, the ready *displacement of the* C S F. *can offer little softening* effect to such forces.

(*a*) *Acceleration* (Fig. 155). When struck violently the force

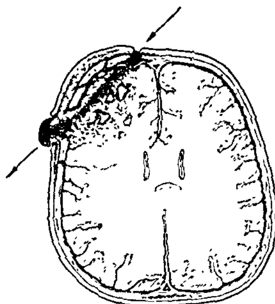


Fig. 157. The damage produced by a bullet wound of the skull. Note the scattering of fragments of bone through the brain tissue. (After Makins.)



Fig. 158. Compound depressed fracture of the frontal bone.

transmitted to the skull may cause it to strike against the brain on the side of impact, as the brain lags behind owing to its inertia. Damage may thus occur at the point of impact without a depressed

fracture occurring, though general deformation of the skull and possibly a fissure fracture may be present.

(*b*) *Deceleration* (Fig. 159). In a similar manner, when the skull is suddenly brought to rest by striking a hard surface such as a metal road, the brain travels on for a fraction of a second and strikes against the surface of impact. At the same time the brain separates from the opposite side of the skull and damage from traction or suction may occur there.

(*c*) *Rotational acceleration and deceleration*. If the head is violently spun by a blow at one or other end of its axis the contents

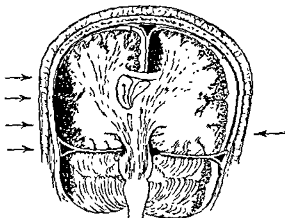


FIG. 159. Effect of deceleration on the skull—single arrow indicates direction of motion, multiple arrows, resistance. The dark areas represent areas of compression, the dotted areas those of damage by traction and rupture.

may be swung against the tentorium or falx. This accounts for the damage frequently found in these regions, for both structures oppose acceleration or deceleration

Contrecoup. This term is used to describe damage on the surface of the brain remote from the side of injury to the skull. Damage here may be due to,

1 Deceleration.

2 Traction from acceleration (suction).

3. The compression of an opposite pole in gross deformations of the skull.

The Clinical Examination of Cases of Head Injury

HISTORY. This usually has to be obtained from witnesses. If conscious and co-operative, the patient may be able to help, but amnesia may cover the most important period, and its length is some measure of the severity of the injury. One must ascertain :

Type of injury, *i e.*, blow, fall, bullet, etc.

Severity of the force, *i.e* . height of fall

Length of time since accident.
Level of consciousness of patient since accident.
If stuporose, whether this has lightened or deepened.

One may be able to learn,

If there is any history of previous skull injury.
If there is any nerve palsy or nervous disease.
If the B.P. is higher than normal.
Whether the patient has been drinking.
If there is a history of fits or previous coma.

If there is no history available the diagnosis from a cerebral hæmorrhage or other lesion may be impossible, especially if there are no facial or other injuries.

Examination. This should be carried out preferably in a separate room, warm, and with a good light, so that the patient may be safely stripped. Associated injuries should be excluded and dealt with temporarily to enable the surgeon to concentrate on the cerebral injury. A detailed note should be kept of all findings.

Inspection,

Position of the patient. Colour. Respiration. Pulse.
Site of laceration, abrasion, hæmatoma.
Type of movements, if any, of the extremities, facial, muscles, and any difference in tone and reflexes.
Bleeding from the mouth, nose or ears, or the escape of cerebrospinal fluid.
Presence of an orbital hæmatoma.
Depth of unconsciousness.

Palpation,

Symmetry of the skull.
Resilience of tissues below the hæmatoma, or abrasion.
Presence of a hæmatoma in neck muscles.
Neck rigidity, or Kernig's sign.

Record the B P., pulse, and respirations, and level of consciousness, and continue to do so hourly.

Proceed to a thorough clinical examination of the C.N.S. if the patient's condition will allow it.

Cranial nerves (1) *Olfactory.* Impossible to test in usual case. Anosmia may be detected later.

2. *Optic.* Ophthalmic examination may reveal retinal hæmorrhages or later papillœdema.

3. *Oculomotor.* Supplies all ocular muscles, but the superior oblique (4) and the lateral rectus (6). Conveys fibres to sphincter

fracture occurring, though general deformation of the skull and possibly a fissure fracture may be present.

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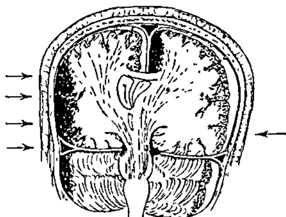


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Type of injury, *i e.*, blow, fall, bullet, etc
Severity of the force, *i e.*, height of fall.

the patient frequently and to note any alterations from the first examination.

LUMBAR PUNCTURE. Although not necessary as a routine, examination of the cerebrospinal fluid may indicate heavy blood contamination from cerebral laceration. If care is taken to remove not more than 1 ml., aggravation of any raised intracranial pressure is not likely to occur.

X-RAY EXAMINATION. This is very important, particularly in compound fractures. Often the patient is too restless in the early stages, and the examination has to be postponed. In addition to the

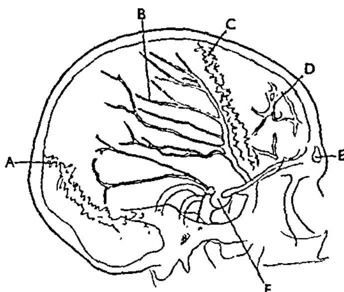


FIG. 160. The radiological markings of the vault of the skull :—
A. The parieto-occipital suture.
B The grooves of the meningeal veins and arteries.
C. The fronto-parietal suture.
D. The diploic venous sinuses.
E. The frontal sinus.
F. The sella-turcica.

fissures which may be seen, in rare cases, particularly fractures of the frontal region, air may escape into the skull or scalp and cast a shadow in the X-ray.

Confusion with the various other lines visible on the skull should be avoided Generally speaking, the fracture line will be sharp and clear cut in at least one view of the skull. It shows no relation to other lines present, which it usually crosses, and it may angle sharply. Suture lines rarely cause confusion on account of their serrations. Meningeal vessels and diploic veins have fairly sharp margins, but they occur in recognised situations. The meningeal vessels branch like a tree and the diploic veins run an irregular course producing patterns with a large mesh.

pupillæ from the cavernous plexus through the short ciliary nerves A lesion may be partial or complete. Complete paralysis gives a divergent squint, ptosis, and a dilated pupil with no reaction to light or accommodation. A dilated pupil alone is more likely to be due *to compression of the third nerve at the tentorial opening by displacement of the brain stem.*

4. *Trochlear.* Supplies the superior oblique. Rarely injured. It is difficult to recognise the palsy, but the patient may complain of diplopia on looking down and in.

5. *Trigeminal.* May be injured in association with facial injuries Loss of perception of touch and pain over face and forehead according to the divisions injured. Corneal reflex may be absent in coma.

6. *Abducent.* Long intracranial course, liable to damage. Paralysis of the lateral rectus with loss of lateral movement of the eye. Convergent squint, with diplopia on looking to affected side.

7. *Facial.* Lesion is usually infranuclear, at the base of the brain *or in the temporal bone. Produces facial asymmetry* and loss of response of facial muscles to irritation. Unconscious patient may blow the cheek out.

8. *Auditory.* Accurate test requires co-operation. Patient may not respond to sounds on that side. May be associated with lesions of the 7th nerve. Vertigo. Tinnitus. Nystagmus.

9 *Glossopharyngeal.* Very rarely involved. Loss of taste over posterior third of tongue.

10. *Vagus.* Paralysis produces palatal paralysis, some difficulty in swallowing, and alteration in voice. The vocal cord assumes the cadaveric position Very rarely injured, and then usually incompletely

11. *Accessory.* Trapezius paralysed, and patient cannot shrug the shoulder

12 *Hypoglossal* Paralysis of the tongue on one side so that on protrusion the unparalysed muscles force tip over to the side of lesion

The examination must include an estimation of the degree of consciousness, and what stimuli may produce reactions in the patient, including the conjunctival and corneal reflexes Note if one side is moved more than the other on stimulation. The size of the pupils is most important and watch should be kept for the development of any irregularity in size and in reactions.

Examination of the limbs may reveal differences in tone and abnormalities in various tendon reflexes which may have an important bearing on the localisation of any focal cerebral damage

Any impediment or irregularity in respiration must be noted.

In any unconscious patient, it is most important to re-examine

to the orbital cavity and hæmorrhages into the orbit. Some squints are due to brain stem lesions of a transient type, probably vascular, and recovery is rapid and complete.

Pupils. Rapid change in size of pupil and varying size of pupil are common, and indicate brain stem lesions of a similar type to the transient oculomotor palsies. The pupillary change indicating pressure is the fixed dilated pupil, which does not respond to light shone into it, or into the opposite eye (consensual reflex), and may be reached by the series of steps shown in Fig. 166. This indicates that the occulomotor nerve is being stretched, by depression of the brain stem, from a rise in supra-tentorial pressure. This is also the most common cause of decerebrate rigidity which occurs after an interval (immediate decerebrate rigidity is due to local brain stem damage). It demands relief from pressure by decompression. It is in these cases that serious complications may follow lumbar puncture, which allows the medulla to prolapse further with resultant increased pressure on it.

Special Clinical Features of Fractures of the Base

These may be due to :

1. External hæmorrhage.
2. Escape of cerebrospinal fluid.
3. Involvement of cranial nerves.
4. Escape of brain matter.
5. Escape of air from the air sinuses.

These features can be grouped according to the fossa affected.

Anterior fossa. HÆMORRHAGE. *Nasal.* Have to exclude blows on the nose or hæmorrhage into the antrum. Occurs from rupture of the cribriform plate.

Oral. Hæmorrhage from the post-nasal region may trickle out of the mouth. Have to exclude oral damage. In this and preceding case the blood may be swallowed and later vomited.

Orbital. Hæmorrhage into the muscles may result in squint. If more severe there may be proptosis, with a dilated inactive pupil. Hæmorrhage into the lids may occur from damage to the ethmoids, frontal sinus, or from blows on the eye. Hæmorrhage from fractures shows itself after a lapse of time, and trickles first into the lower lid. There is no sign of external damage, and when it passes below the conjunctivæ it forms a wedge with its base in the lateral fornix, and extending inferiorly, and with the following characteristics :

1. The hæmorrhage is limited by the palpebral fascia to the orbital margins and tends to be circular.
2. There is no posterior limit to the conjunctival hæmorrhage.
3. The conjunctiva itself is not injured or œdematous.

Analysis of Clinical Findings

The analysis of the signs and symptoms of cerebral injury is not simple. This is due to the uneven and widespread distribution of the lesions and the uncertain mechanism underlying cerebral states such as concussion. Over the whole is placed the blanketing action of unconsciousness in most cases.

UNCONSCIOUSNESS is the most conspicuous feature of any severe head injury, and varies considerably in depth. In the mildest forms the patient is merely dazed and may be able to continue his activity with merely some impairment of efficiency, *e.g.*, the stunned footballer. The patient may present various degrees of confusion.

Mild. A state in which the patient, though presenting the characteristic feature of confusion in some degree, is capable of coherent conversation and appropriate behaviour.

Moderate. A state in which the patient, though out of touch with his surroundings, can give relevant answers to simple questions, such as "What work do you do?" "How old are you?" "Where do you live?"

Severe. A state in which the patient, though for the most part inaccessible, will occasionally show adequate response to simple commands forcibly given, and, if necessary, reinforced by appropriate gestures, *e.g.*, " Put out your tongue," " Take my hand."

The next stage is the stage of stupor in which the patient may be made to give some response, *e.g.*, to screw up the face when pressure is placed on the supraorbital nerve. The swallowing and corneal reflexes are present, and the patient will usually evacuate a full bladder when discomfort occurs incontinently.

In coma, the deepest state of unconsciousness, the patient is completely inert and may not respond to any stimulus. Retention of urine and overflow are usual. The corneal and swallowing reflexes may or may not be present. It is indicative of severe damage to the brain and the longer it lasts the more serious the outlook. A change in the patient's state of consciousness is a most important prognostic sign for good or ill.

POSITION OF THE PATIENT. This is dependent in the unconscious on the distribution of muscle tone throughout the body, and is profoundly modified by damage to the various centres whose pathways control the lower motor neurones. Damage may occur at various levels in the brain and brain stem, and in various combinations which account for the complicated and changeable features met with. Hemiplegia, monoplegia, convulsive twitching and changes in muscle tone, should all be noted and assessed.

Eye muscles. These may be thrown out of action by other causes than nerve palsy, and watch has to be kept for the effects of damage

to the orbital cavity and hæmorrhages into the orbit. Some squints are due to brain stem lesions of a transient type, probably vascular, and recovery is rapid and complete.

Pupils. Rapid change in size of pupil and varying size of pupil are common, and indicate brain stem lesions of a similar type to the transient oculomotor palsies. The pupillary change indicating pressure is the fixed dilated pupil, which does not respond to light shone into it, or into the opposite eye (consensual reflex), and may be reached by the series of steps shown in Fig. 166. This indicates that the occulomotor nerve is being stretched, by depression of the brain stem, from a rise in supra-tentorial pressure. This is also the most common cause of decerebrate rigidity which occurs after an interval (immediate decerebrate rigidity is due to local brain stem damage). It demands relief from pressure by decompression. It is in these cases that serious complications may follow lumbar puncture, which allows the medulla to prolapse further with resultant increased pressure on it.

Special Clinical Features of Fractures of the Base

These may be due to :

1. External hæmorrhage.
2. Escape of cerebrospinal fluid.
3. Involvement of cranial nerves.
4. Escape of brain matter.
5. Escape of air from the air sinuses.

These features can be grouped according to the fossa affected.

Anterior fossa. HÆMORRHAGE. *Nasal.* Have to exclude blows on the nose or hæmorrhage into the antrum. Occurs from rupture of the cribriform plate.

Oral. Hæmorrhage from the post-nasal region may trickle out of the mouth. Have to exclude oral damage. In this and preceding case the blood may be swallowed and later vomited.

Orbital. Hæmorrhage into the muscles may result in squint. If more severe there may be proptosis, with a dilated inactive pupil. Hæmorrhage into the lids may occur from damage to the ethmoids, frontal sinus, or from blows on the eye. Hæmorrhage from fractures shows itself after a lapse of time, and trickles first into the lower lid. There is no sign of external damage, and when it passes below the conjunctivæ it forms a wedge with its base in the lateral fornix, and extending inferiorly, and with the following characteristics :

1. The hæmorrhage is limited by the palpebral fascia to the orbital margins and tends to be circular.
2. There is no posterior limit to the conjunctival hæmorrhage.
3. The conjunctiva itself is not injured or œdematous.

Analysis of Clinical Findings

The analysis of the signs and symptoms of cerebral injury is not simple. This is due to the uneven and widespread distribution of the lesions and the uncertain mechanism underlying cerebral states such as concussion. Over the whole is placed the blanketing action of unconsciousness in most cases.

UNCONSCIOUSNESS is the most conspicuous feature of any severe head injury, and varies considerably in depth. In the mildest forms the patient is merely dazed and may be able to continue his activity with merely some impairment of efficiency, *e.g.*, the stunned footballer. The patient may present various degrees of confusion.

Mild. A state in which the patient, though presenting the characteristic feature of confusion in some degree, is capable of coherent conversation and appropriate behaviour.

Moderate. A state in which the patient, though out of touch with his surroundings, can give relevant answers to simple questions, such as "What work do you do?" "How old are you?" "Where do you live?"

Severe. A state in which the patient, though for the most part inaccessible, will occasionally show adequate response to simple commands forcibly given, and, if necessary, reinforced by appropriate gestures, *e.g.*, " Put out your tongue," " Take my hand."

The next stage is the stage of stupor in which the patient may be made to give some response, *e.g.*, to screw up the face when pressure is placed on the supraorbital nerve. The swallowing and corneal reflexes are present, and the patient will usually evacuate a full bladder when discomfort occurs incontinently.

In coma, the deepest state of unconsciousness, the patient is completely inert and may not respond to any stimulus. Retention of urine and overflow are usual. The corneal and swallowing reflexes may or may not be present. It is indicative of severe damage to the brain and the longer it lasts the more serious the outlook. A change in the patient's state of consciousness is a most important prognostic sign for good or ill.

POSITION OF THE PATIENT. This is dependent in the unconscious on the distribution of muscle tone throughout the body, and is profoundly modified by damage to the various centres whose pathways control the lower motor neurones. Damage may occur at various levels in the brain and brain stem, and in various combinations which account for the complicated and changeable features met with. Hemiplegia, monoplegia, convulsive twitching and changes in muscle tone, should all be noted and assessed.

Eye muscles. These may be thrown out of action by other causes than nerve palsy, and watch has to be kept for the effects of damage

A fracture of the posterior fossa may involve the jugular foramen, but the nerves in this foramen are rarely injured.

Special Treatment of these Symptoms

Hæmorrhage or the discharge of C.S.F. from the nose. If small, leave alone. Syringing is absolutely contra-indicated owing to the risk of infection.

A bleeding ear may need cleansing on the exterior to be certain that the blood has not run into it from outside. If bleeding is coming from the drum the external ear should be cleaned with spirit and left. Syringing is dangerous. If there is a free discharge of blood there is a rare possibility of a middle meningeal hæmorrhage being externalised. A pad over the ear to absorb the discharge, whether C.S.F. or blood, is all that is allowable.

Considerations regarding Brain Damage

The importance of a head injury lies mainly in the severity of brain damage. The brain may suffer concussion, contusion or laceration ; it may be compressed by an effusion of blood or infection of the intracranial contents may occur if the fracture is open. The clinical picture presented will indicate the nature and severity of the cerebral insult.

Concussion

This is characterised by immediate loss of consciousness following a head injury. The patient, if seen within a few minutes of the injury, will present, in addition to unconsciousness, pallor of the skin, flaccidity of the limbs, shallow respirations and a slow feeble pulse All reflexes are usually absent, including the pupillary and corneal. The duration of concussion varies with the severity of the injury. Recovery is usually rapid if the blow has not been severe and is often ushered in by vomiting. On recovering consciousness, the patient often complains of headache and there may be irritability and restlessness and higher mental faculties may be impaired for some hours, but in uncomplicated concussion these symptoms disappear within twenty-four hours. There may be loss of memory for some of the period immediately following the injury—post-traumatic amnesia—and this loss may include events prior to the injury—retrograde amnesia.

Physiology of Concussion

Trotter's description of concussion has received general acceptance. He described it as a transient state of unconsciousness coming on immediately following a blow to the head, associated with wide-

ESCAPE OF C.S.F. It may escape from the nose due to cribriform damage, giving rise to the condition known as traumatic rhinorrhœa.

BRAIN MATTER may also escape, in either case the importance of the observation is due to the attendant risk of infection.

ESCAPE OF AIR. Air from the ethmoids or the frontal sinus may form localised crepitant collections under the scalp.

INJURY TO NERVES. The nerves involved may be the olfactory or the optic, unilateral or bilateral, The extent of the injury can only be assessed later.

Middle fossa. HÆMORRHAGE. *From the nose and mouth.* Due to fracture of the sphenoid body. Both the cavernous sinus and

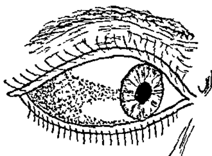


FIG 161 The appearance of sub-conjunctival hæmorrhage in fracture of the skull.

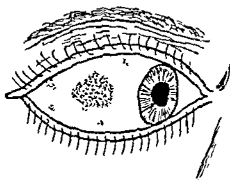


FIG. 162. The appearance of sub-conjunctival hæmorrhage due to a blow directly over the eye.

the internal carotid may be injured, giving rise in some cases to an arteriovenous aneurysm.

Aural. This is pathognomic of middle fossa fracture, if damage to the external auditory meatus is excluded.

C.S.F. may also escape from the ear.

BRAIN MATTER has also been observed to discharge from the ear.

AIR may escape from damage to the mastoid air cells.

INJURY TO NERVES due to involvement in the fissuring of the petrous temporal may occur to the trigeminal, the abducent, the facial, and the auditory. In injuries the hæmorrhage may so damage the drum that the impairment of hearing cannot be assessed till later. Disturbances of the vestibular division are common.

Posterior fossa. HÆMORRHAGE May occur into the tissues of the neck, with stiffness and the late appearance of bruising, or into the scalp in the mastoid region

THE C.S.F. and brain matter have no channels for escape, except in severe compound injuries.

INJURY TO NERVES The auditory or the hypoglossal may be involved, or the facial, from a crack across the petrous temporal bone.

A fracture of the posterior fossa may involve the jugular foramen, but the nerves in this foramen are rarely injured.

Special Treatment of these Symptoms

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A bleeding ear may need cleansing on the exterior to be certain that the blood has not run into it from outside. If bleeding is coming from the drum the external ear should be cleaned with spirit and left. Syringing is dangerous. If there is a free discharge of blood there is a rare possibility of a middle meningeal hæmorrhage being externalised. A pad over the ear to absorb the discharge, whether C.S.F. or blood, is all that is allowable.

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Physiology of Concussion

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spread paralysis of brain function with a strong tendency to spontaneous *recovery and without evidence of structural brain damage.* The experimental work of Denny-Brown and Russell has shown that concussion is brought about by widespread disturbance of cerebral neurones without evidence of organic injury and that the speed of recovery is proportional to the severity of the injury.

Treatment of concussion without fracture. At the time of the accident all that can be done is to see that the patient lies in a comfortable position with a free airway till he can be put to bed. Stimulants are usually forced on the unconscious by the laity and may later form the grounds for an accusation of drunkenness As concussion without further complication recovers spontaneously in a short period at the most, the only treatment to be discussed is that of the rest necessary afterward. The length of this must be governed by the length of time concussion lasted, the association of other injuries, the age and general condition of the patient, the type of mental work the patient does, and the presence of headache. In the milder cases, treatment may not be necessary. When there has been no headache for a day or two, gradually increasing mental and physical activity can be undertaken.

Cerebral Contusion and Laceration

These follow a more severe head injury. Hæmorrhages—subpial or intracerebral—occur and involve various parts of the hemispheres, disrupting the grey and white matter. They are most commonly found at the point of impact, or at a distance—from contre-coup Bony buttresses and the rigid falx and tentorium will also contuse or lacerate the brain if the motion imparted to it is severe enough Contusion and laceration of the brain will vary with the nature of the injury and may indeed be severe enough to prove fatal



Fig. 163. The posture in cerebral contusion. The body lies curled up, and the face is turned away from the light. A fracture of the lower end of the tibia has been immobilised in plaster

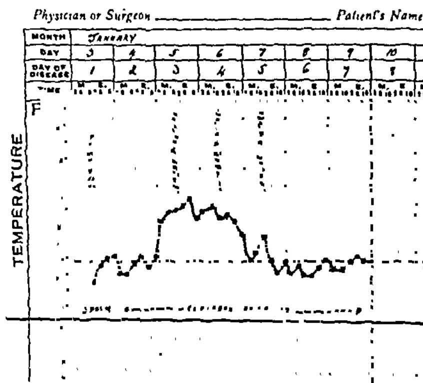


FIG. 164. The temperature chart in a case of cerebral contusion.

SYMPTOMS

The patient is usually unconscious and this will vary with the severity of the brain damage. If vital centres are involved the injury may indeed prove fatal. A moderately severe contusion presents the typical clinical picture known as " cerebral irritation " or traumatic delirium. The patient is stuporose, usually lies on the side, resenting disturbance, when roused he may be noisy and even violent and is usually confused and disorientated. Incontinence is usually present, although in the less severe injuries the patient may void voluntarily. The stupor is of varying duration and may last for weeks. In favourable cases it is followed by a gradual return to normality. During the recovery period focal damage to the cerebral cortex may become evident (mono- or hemiplegia, aphasia, convulsions, hemianopia) or evidence of damage to the brain—ocular nerve palsies.

Return to normality may be retarded by the appearance of " post-contusional syndromes " of which paroxysmal headache, giddiness, loss of memory and inability to concentrate are the most common features. Headache tends to be aggravated by noise and by mental and physical effort. The patient is easily fatigued, the emotions are quickly upset and anxiety state frequently develops. Personality changes and intellectual impairment may develop after the more severe grades of injury.

Treatment

Nursing care is of the greatest importance to the unconscious patient. He should be nursed on his side with the head pillowed low enough for secretions to flow out and for the airway to be clear, and the position should be changed from side to side every two hours. Frequent oral hygiene with moistened gauze and gentle suction with a rubber catheter assists in keeping the pharynx and larynx clear. In the more severe cerebral injuries, particularly when facial injuries make it difficult to maintain a clear airway, tracheotomy can be extremely helpful. Intramuscular penicillin, 250,000 units six-hourly, should be given if there is unconsciousness of more than a few hours' duration to prevent respiratory infection. Established infection requires higher doses or a change of antibiotic according to the organism. Pyrexia of over 103° F. may require such measures as ice-cold water applications to the skin and is usually of bad prognostic significance.

FLUID AND FOOD

Fluids can be administered to the unconscious patient via the rectum, but food must be given by way of a rubber œsophageal tube passed through the nose if unconsciousness is still present after eighteen to twenty-four hours. Auscultation over the stomach while air is injected into the tube will demonstrate air bubbles and thus ensure that the tube is not in the trachea. With proper precautions the nutrition of the patient can be maintained by this means for a long time. In those unconscious for any length of time, biochemical estimations of the blood plasma will assist in the prevention of possible metabolic disorders

As consciousness returns, the ability to swallow can be tested by sucking a moist swab placed between the lips. If sucking and swallowing are possible, then increasing fluids by spoon and cup are given, to be followed by natural feeding.

RESTLESSNESS may be due to thirst, to a full bladder, or to headache, and should be treated accordingly. If it persists, mild sedation with chloral hydrate and potassium bromide (30 gr. of each) given per rectum or by nasal tube should be tried. For the more severe grades of restlessness or violence, phenobarbitone (3 gr) or paraldehyde (3–5 ml) should be given intramuscularly. The possibility that headache may herald cerebral compression should be considered before administering any drugs. It may respond to "Dispirin" or "Veganin." Where these fail, posture or the rectal administration of 6 oz. of 50 per cent. Magnesium sulphate may be successful. Morphine should not be given.

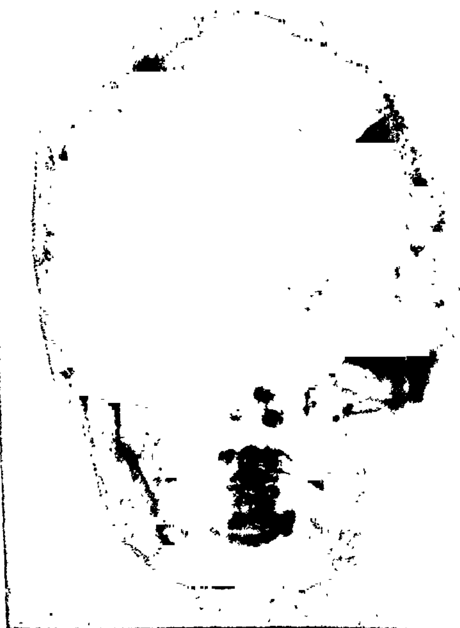


FIG. 165. Massive fracture of the frontal bone. The free bone fragment was depressed in the lateral film. Death in eight hours.

LUMBAR PUNCTURE may be informative, provided precautions are taken not to remove more than 2 ml. in the early stages when compression may be present. The procedure is without danger in the absence of compression and the removal of bloodstained cerebrospinal fluid may relieve headache. In the presence of fever, lumbar puncture is also indicated and may reveal an unsuspected meningitis.

RECOVERY. With recovery of consciousness the patient may take

up any position of comfort in bed and changes in his surroundings will be dictated by signs of overt cerebral damage and by his subjective symptoms—giddiness, headache, irritability, etc. Convalescence can be expedited by sympathetic understanding and advice, by diversional, occupational and physical therapy, according to the disability of the patient.

Traumatic Cerebral Compression

The early diagnosis of this condition is of the utmost importance. It has already been stressed that in every case of head injury a detailed investigation of the central nervous system and of the degree of stupor should be recorded when the patient is first seen Certain alterations from the original picture may enable a diagnosis

PUPILLARY CHANGES IN CEREBRAL COMPRESSION.

Stage.	PUPIL ON SIDE OF COMPRESSION	PUPIL ON OPPOSITE SIDE.
1.	Slightly contracted ●	Normal. ●
2.	Moderately dilated Reacts to light. ●	Normal. ●
3.	More dilated. Does not react to light. ●	Moderately dilated. Reacts to light. ●
4.	Widely dilated, and insensitive. ●	Widely dilated, does not react to light. ●

Fig. 166.

of compression to be made. Increasing headache may be the first symptom and should always be regarded with suspicion. Cerebral compression leads to *progressive increase in unconsciousness*, the patient failing to respond to stimuli that previously roused him. Of particular importance is stupor after consciousness has been regained —*the lucid interval* There may be evidence of a progressive unilateral cerebral lesion, *e g.*, hemiplegia and an extensor plantar response. Focal irritation may produce convulsions on the opposite side. The fundi may reveal increasing fullness of the veins or, *more rarely, papillœdema* *Pupillary changes are of the greatest* importance ; the pupil on the side of compression is at first contracted, then dilated, and finally dilated and insensitive to light—a sign of ill omen If compression continues, similar changes occur in the pupil of the opposite side, to be followed by evidence of compression of the medulla ; the pulse is full and slow, later becomes rapid and irregular. Respirations are at first slow, deep and often stertorous, later becoming irregular and of the Cheyne-Stokes type.

Pathology of Cerebral Compression

Head injuries produce cerebral compression by hæmorrhage from laceration of blood vessels, extradural or subdural hæmorrhage being the commonest manifestations. With timely diagnosis these lend themselves to surgical intervention.

Extradural hæmorrhage occurs most commonly from the middle meningeal vessels. Sometimes the source of bleeding is from the dural venous sinuses or from diploëic vessels. A fracture line may give a clue to the localisation of the bleeding. In bleeding from the middle meningeal vessels, blood accumulates rapidly and

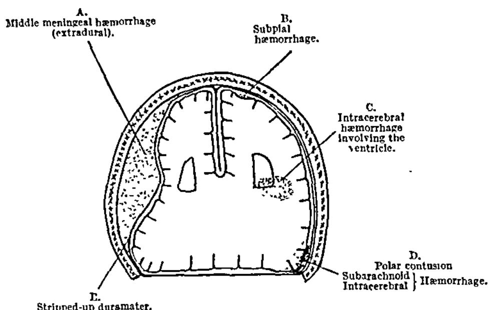


Fig. 167. Diagrammatic representation of the various types of hæmorrhage met with in skull injury.

the dura is stripped from the overlying skull. The latent period (if any) is short—a matter of hours only—and unless the hæmorrhage is evacuated it is rapidly fatal. If a fracture is present, the intracranial collection may communicate with a hæmatoma outside the skull, often subtemporal.

Subdural hæmorrhage arises from veins passing from the surface of the brain to the dural venous sinuses and the blood accumulates in the space between arachnoid and dura and may be bilateral. The blood usually accumulates more slowly than in the extradural form and the evolution of the picture of compression may be spread over a period of days and even weeks. It must be stressed, however, that acute forms are not uncommon, simulating extradural hæmorrhage. In the more chronic variety the hæmorrhage becomes encapsulated and if the head injury has been apparently trivial, the

condition may simulate a cerebral thrombosis or a cerebral tumour. A condition simulating subdural hæmatoma may be caused by cerebrospinal fluid escaping through a tear in the arachnoid membrane and collecting in the subdural space—subdural hygroma.

LOCALISED INTRACEREBRAL HÆMATOMAS may occur but are much less frequent than the preceding varieties. Occasionally, and particularly in the elderly, local contusion after an interval of some days may result in hæmorrhage from necrosis of vessels—" spät apoplexie."

Intra-Cranial Hæmorrhages in Relation to Time

Site	Latent Period.	Paralytic Signs.
EXTRADURAL	Variable, usually a few hours.	Face and arm. Speech in L.-sided lesions. Twitching going on to a spastic paralysis.
SUBDURAL	Localised { Acute, 4 to 7 days. Chronic, 6 to 12 weeks.	Legs involved. Signs variable, like a cerebral tumour.
SUBARACHNOID	Diffuse. Immediate.	
CEREBRAL.	Immediate.	Spastic monoplegia. Hemiplegia.
	Late, 7 to 10 days. (Spat apoplexie.)	Spastic monoplegia.

Treatment

MIDDLE MENINGEAL HÆMORRAGE must be promptly evacuated. No operation is more urgent. The main vessel and its branches can be exposed under local anæsthesia by a hockey-shaped incision over *the middle of the temporal fossa extending from the zygoma $2\frac{1}{2}$ inches* vertically and curving backwards for $\frac{3}{4}$ inch. The temporal fascia is divided vertically with cross cuts above and below and the thin bone nibbled away after making a burr hole. The bony opening can be extended in any direction until the bleeding point is seen. The bleeding vessel can be controlled by a tie, a silver clip, or by coagulation or by plugging the foramen spinosum. If the bleeding appears to be coming from the diploe bone wax will control it. Bleeding from one of the venous sinuses is more difficult to localise. If it is possible to do this, the bleeding should be controlled by the application of gel-foam or muscle fragments.

SUBDURAL HÆMATOMA. Where localising signs are present, a

½-inch burr hole is made through an appropriate small vertical incision. The dura mater presents a bluish discoloration in the presence of a hæmatoma beneath it. A crucial incision is made in the dura and the hæmatoma is evacuated by suction. The evacuation is often assisted if the hæmatoma is large by making a second burr hole further forwards or backwards and irrigating gently into the cavity with warm saline. Several inspection burr holes may be necessary if the subdural hæmatoma is not encountered through the first. The frequency of bilateral collections makes similar exposures on the opposite side desirable. In most cases, two burr holes in the position of (1) and (2) in Fig. 168 with similar holes on the opposite side suffice. No attempt is made to find the bleeding point for the vessels seal off naturally once the hæmatoma is evacuated. A small drain may be placed down through the dural opening for forty-eight hours.

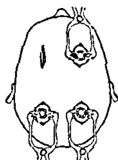


Fig. 168. The position of the burr holes for exploration for a subdural hæmatoma.

Intracerebral hæmatoma. If extradural and subdural hæmorrhage has been excluded by exploration, the presence of an intracerebral collection may be suspected by the increased pressure seen through the inspection burr holes. A ventricular needle inserted gently into the brain may be successful in locating it and by suction with a rubber-topped syringe it may be possible to evacuate it through the needle. A small osteoplastic flap, however, is usually needed for complete evacuation.

Differential Diagnosis of Cerebral States following Head Injury

In any patient who is unconscious, non-traumatic conditions which can produce coma must always be considered—cerebral hæmorrhage, epilepsy, diabetes, alcoholism, or uræmia. In these conditions it is possible for the patient to acquire a head injury in falling. A detailed account of the episode or accident from witnesses, the past history of the patient from relatives, and a complete examination will aid in elucidating the problem.

In concussion the loss of consciousness is short and is usually a matter of minutes. If there is delay in the return to full consciousness for more than this, or if there is evidence of a focal lesion, then contusion or laceration has occurred. Unconsciousness may continue in this condition for days or weeks. It may vary in intensity and periods of delirium or confusion are common. Neck stiffness, if present, may be caused by the extravasation of blood in the subarachnoid space or by the development of meningitis from a

compound fracture. Lumbar puncture is necessary for differential diagnosis.

The diagnosis of cerebral compression can be easy if the patient has recovered from concussion and is able to reveal the development of headache and increasing drowsiness. Difficulty in diagnosis may be presented by those cases in which there is no recovery of con-

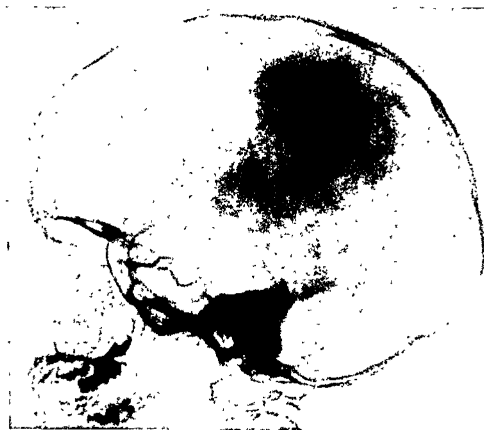


Fig. 169. A fissure fracture of the parietal, running into the parieto-occipital suture.

sciousness and where compression slowly increases the depth of coma. The paralytic phenomena already described may indicate the presence of compression, but the sheet anchor in differential diagnosis lies in a full clinical investigation of the basic state of the patient when first seen, followed by frequent and close observation to detect any alteration in the depth of coma, the rapidity of deterioration and the presence of paralytic features or signs of focal damage. When the level of unconsciousness does not improve, and when there is any suspicion of compression, inspection burr holes must be made in the skull, preferably on both sides.

The Sequelæ of Head Injury

1. THE POST-CONTUSIONAL SYNDROME with its symptomatology has already been mentioned. Sympathetic and reassuring handling by doctors and employers until the patient is rehabilitated is essential. Headache may be a troublesome feature when other symptoms have gone and may require a continuation of analgesics. Its duration and severity varies with the personality of the patient.

2. FOCAL DAMAGE to the brain may cause permanent cortical damage according to the severity and extent of the injury. Encephalography may reveal areas of atrophy made manifest clinically by intellectual deficits, paresis, dysphasia, visual field defects, etc., according to the area involved. Considerable improvement may eventually occur, but some permanent disability may remain.

3. EPILEPSY may occur in the early stages after a head injury or may become manifest only after several months. In the early stages, fits are due to local damage, either direct or from the irritation or pressure of extravasated blood. The fits may be localised or general and are seen most frequently after severe injuries, particularly in those with open fractures of the vault with penetration of the dura mater. In all cases with penetration of the dura mater, phenobarbitone gr. ½ twice daily (for adults) should be given for a period of five years in order to diminish the risk of epilepsy. Much can be done in prevention by proper debridement at the time of operation, paying particular attention to the removal of all foreign bodies and by careful repair of the dura mater.

4. INJURY TO CRANIAL NERVES. Only those frequently injured will be considered.

(i) *Olfactory.* Total or complete anosmia may result and the loss is usually permanent.

(ii) *Optic nerves and optic chiasma.* Damage to these structures will result in varying degrees of permanent visual defect.

(iii.), (iv.), (vi.) } Any damage sustained to these nerves or to the extrinsic ocular muscles can often recover.

(v.) Injury usually occurs to its peripheral branches causing patchy anæsthesia of the face.

(vii.) This nerve is often injured in the facial canal in fractures of the temporal bone. There is a strong tendency to recovery.

(viii.) Deafness from injury to the auditory nerve is usually permanent.

5. Cerebrospinal rhinorrhœa associated with fractures of the anterior fossa frequently stops spontaneously within a few days. If the patient is conscious, an upright position will help in this direction. While fluid is escaping and for some days afterwards, penicillin and sulphadiazine should be given daily to diminish the risk of meningitis. If the flow of fluid continues after four or five days, the dural tear must be repaired by a fascial repair through a frontal osteoplastic flap.

6. Infection. Meningitis, extradural abscess, or intracerebral abscess and osteomyelitis of the skull may follow compound injuries, particularly those with penetration. The diagnosis of these complications presents no difficulty. Prophylactic administration of penicillin and sulphadiazine with careful debridement of the damaged area and the closure of dural defects will minimise the incidence.

The Treatment of the Skull Fracture

1. Simple linear fractures need no treatment. If the bone has been depressed, the depression should be elevated through a small trephine hole. The pond-shaped fractures of the skull of new-born children need no treatment if the depression is small ; it will disappear as the child grows. With marked depression, the bone can be elevated through a small trephine hole.

2. Compound fractures. These are of infinite variety and treatment will vary accordingly. The main principle in treatment applies to them all—the prevention of infection, the removal of foreign bodies, and the repair of the tissues injured. X-ray studies are a useful guide to correct treatment and suitable chemotherapy should be instituted in them all. In extensive lacerations, blood loss may have been serious and blood transfusion is necessary. The skin should be shaved for an area of at least 3 inches around the wound. Small open wounds associated with linear fractures may require enlargement in order to inspect the fracture. A small self-retaining

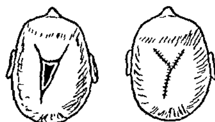


Fig. 170. One method of closing the skin of the scalp after loss of tissue.

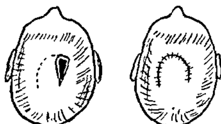


Fig 171 Method of closing a gap in the scalp tissues by using a U-shaped incision. Either this or an S-shaped incision is usually most satisfactory.

ventricular or mastoid retractor is extremely useful in examining the depths of the wound. Devitalised tissues and foreign matter should be removed. Hairs are often in the fracture and must be removed. Very little skin need be removed as a rule. If there is any sign of skull depression or evidence of intracranial damage in the vicinity of the fracture, an inspection trephine hole alongside the fracture should be performed. In all cases the standard method of scalp closure should be employed, *i.e.*, with interrupted fine silk sutures

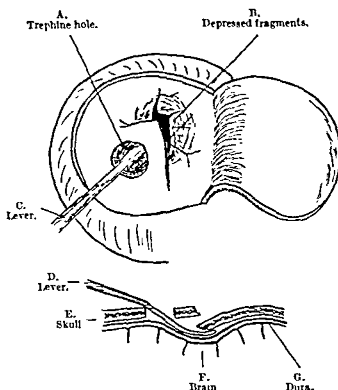


FIG. 172. The elevation of depressed fragments by inserting a lever through a trephine hole on the edge of the fracture.

first for the galeal layer and then for the skin. If the scalp wound is extensive, such devices illustrated in Figs. 170 and 171 may be needed.

3. COMPOUND COMMINUTED FRACTURES. Exposure of the fractured area may be obtained either by extending the original wound or by reflecting a suitable skin flap (Fig. 173). The latter is particularly useful where penetrating injuries, *e.g.*, bullet wounds, have been sustained and where exploration of the track of a foreign body is needed. After toilet of the superficial wound, loose fragments of skull must be removed. A trephine opening close to the margin of the comminuted bone allows inspection, and by extension with bone forceps into the fracture, the depressed fragments can be elevated or if necessary removed. If the dura mater has been torn, lacerated

brain tissue may protrude. It can be removed by gentle suction through a soft rubber catheter. The track left by a penetrating foreign body, *e.g.*, bone or bullet, should be gently irrigated after removal of the foreign body and any necrotic brain tissue removed by suction. It is not wise to enlarge the dural opening. This should be sutured at the end of the operation. If areas of the dura have been destroyed, a free graft of fascia lata may be necessary to cover the underlying brain. In severe injuries with marked comminution and depression, removal of depressed fragments may leave a large bony defect ; this will need closure by bone graft at a later date.

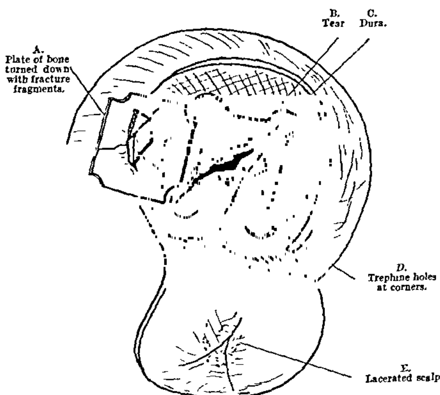


Fig 173. Trephining *en bloc* to remove a large number of depressed fragments combined with exploration.

It may be useful here to list the causes of death in cases of head injury, as a guide to the complications to be expected, and avoided if possible.

	Per cent
Due to massive brain injury, shock and hæmorrhage in severe fractures, the patients dying under ten hours	25
Cerebral compression Death usually in twenty-four hours	45
Pneumonia	5
Exhaustion	3
Meningitis	8
Other lesions and associated injuries	14

Errors in diagnosis of fracture of the skull and interpretation of symptoms

Old fractures of the skull remain visible in the X-ray up to ten years.

Patients may have a bradycardia and hypertension before admission.

A dilated pupil, or irregular pupil, may be an old lesion.

A stroke may have preceded the fall which fractured the skull.

A fracture line should not be confused with a suture line, which is much more irregular and less sharp in outline, in either the X-ray or at the bottom of an open wound.

The sulcus of the middle meningeal artery should not be confused with a fracture line.

A bleeding ear may be due to separation of the cartilage from the bone, and may occur after blows on the jaw.

A bleeding nose is commonly due to local injury.

A black eye should not be confused with hæmorrhage into the orbit from fracture. (See page 218.)

Confusion should not occur between the syndrome arising from meningeal infection and that from compression.

The difficulty of diagnosing a hæmatoma of the scalp from a depressed fracture is easily settled, but much more commonly a fracture is suspected when it is not present than overlooked when it is present.

FURTHER READING

TROTTER and TAYLOR. The Scalp Skull and Brain. Choyce's "System of Surgery."

RIDDOCH, JEFFERSON, RUSSELL and ROSS. "Discussion on the Diagnosis and Treatment of Head Injuries," *Proc. Roy. Soc. Med.*, 1932, 5, 735.

ROWBOTHAM, G. F. "Acute Injuries of the Head." Livingstone, Edin., 1949.

NORTHFIELD, D. W. C. "Treatment of Head Injuries," *Brit. Med. J.*, 1953, 1, 10.

CHAPTER XVI

FACIAL FRACTURES

(Mr. J. N. Barron, F.R.C.S.)

1. UPPER FACIAL FRACTURES

General Remarks. These fractures may be divided for discussion into those of the nasal, malar and maxillary regions. Nasal fractures may involve the nasal bones, the frontal processes of the maxillæ, the ethmoid and lachrymal bones, and the septal, alar and lateral cartilages. Malar fractures may involve the body of the malar, the zygomatic arch, the frontal process, the infra-orbital ridge and the adjacent maxilla, including the anterior antral wall with the infra-orbital canal, and the orbital floor. Fractures of the maxilla may affect the body and the various processes. The maxillary antrum affords a space into which fragments can be displaced.

These injuries are the result of direct violence, and there is little tendency to spontaneous alteration in position of the fragments after the impact owing to the paucity of muscle attachments and the splinting effect of the soft tissues of the face.

Apart from cosmetic reasons, the indications for treatment are visual and sensory disturbances, nasal blockage and its sequelæ and dental mal-occlusion. Inadequate reduction and splintage may have serious results because secondary correction is difficult and late restoration of the displaced bony fragments often impossible.

Cranial fractures are commonly associated with these injuries, and routine examination should include the cervical spine and peripheral nervous system for intracranial and cord damage. A fracture dislocation of the cervical spine should not be missed.

Nasal Fractures

Fractures of the nose are due to direct violence applied to the nasal bridge The violence may be either from in front or from the side, and the resulting deformities are somewhat different. Most nasal fractures are comminuted and this has an important bearing upon the deformity and the treatment.

Compression fracture Blows from in front have a crushing effect, the fragments collapsing upon each other produce a " saddle " or depressed bridge. The whole bony structure may be involved, and in severe cases the ethmoid, with its cell complex, is splayed out

into the orbital cavities. The cribriform plate and dura may give way, in which case direct contact is established with the subdural space in the region of the gyrus rectus of the frontal lobe. This is



FIG. 174. Saddle nose resulting from head-on blow.



FIG 175. Nasal deviation due to lateral injury.

indicated by the appearance of cerebrospinal rhinorrhœa. The septum is buckled or fractured and the mucous membrane stripped from the underlying bone and cartilage so that a submucous hæmatoma may result.

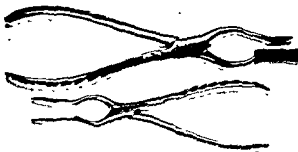


FIG. 176. Rubber-covered Walsham's forceps used in disimpacting nasal bones.
Asches' septal forceps for manipulation of septal deformities.

DEVIATION FRACTURE Lateral injuries involve the nasal bones and septum. The main deformity is a deviation of the bridge, the fragmented bone on the side of impact being driven under the opposite side, which may itself be fractured. The septum is deviated from the side of injury and is buckled or broken.

Treatment. Nasal fractures should be reduced at the earliest

opportunity. If there is early gross œdema it is justifiable to encourage its absorption by the use of alternate hot and cold packs for a few days before reduction is attempted. Reduction is most readily obtained by the use of Walsham's nasal forceps and Asches' septal forceps. Each nasal bone in turn is disimpacted with Walsham's forceps and elevated into its normal position. The septum is then held lightly between the blades of the Asches forceps and straightened out, the nasal bridge being elevated at the same time. Any tendency to splaying at the base of the nose is controlled by the fingers during this last manœuvre. Long rubber-covered forceps of

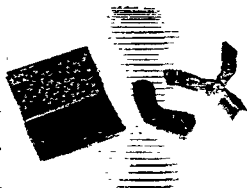


Fig 177. Plaster nasal splint to maintain mid-line position after reduction of fracture deviation



Fig. 178. The method of making a plaster nasal splint.

any pattern can be used for this manipulation if the proper instruments are not available.

Where a crush fracture involves the ethmoids and there is lateral displacement into the orbits it is of the utmost importance that this should be corrected With the septum held steady in the elevated position, the thumb and forefinger of the left hand are passed back into the orbits along the inner canthi. The lateral masses of the ethmoids are then squeezed back into their normal relationship in the nasal cavity.

Splintage. In minor fractures no splintage is necessary. Care should be taken that no further trauma is inflicted during the first fortnight. Where there has been much comminution and displacement a plaster of Paris pattern should be cut and moulded over the nose. It should have an extension on to the forehead and is fixed by strapping. In some cases where there is a tendency for the

whole bridge to collapse a stout silk mattress suture is passed through the nose and tied over small wood rolls. This provides a satisfactory and stable splint. A light vaseline gauze pack should be introduced into each nasal cavity for forty-eight hours.

Anæsthesia. The nose should be packed half an hour before operation with 10 per cent. cocaine and ·01 per cent. adrenaline. All but minor reductions should be done under endotracheal anæsthesia to obviate the risk of inhaled blood. Bleeding can be profuse in these operations.



Fig. 179. Silk mattress-stitch passed through the *nose and tied over dental* rolls. This splint will maintain elevation of depressed fractures.

Malar Fractures

(A) Malar Zygomatic Fractures. The simplest fracture in this region is a depressed fracture of the zygomatic arch. Minor displacements may cause little or no functional or cosmetic disability, but in more extensive injuries the fragments impinge upon the underlying temporal muscle insertion and cause persistent trismus.

Force applied to the body of the malar may cause separation at the malar-maxillary, fronto-malar and zygomatic suture lines (see Fig. 165). The bone is depressed and rotated inwards, and flattening of the cheek results. Examination should be made from above and behind the patient so that contours can accurately be compared. Palpation reveals a step deformity in the infra-orbital ridge and separation at the fronto-malar suture. There may be a palpable separation in the zygomatic process but this is usually "sprung," the malar rotating inwards about this point. Swelling of the cheek and lids and subconjunctival ecchymosis are associated with this fracture, and œdema may be so great as to mask the underlying bony injury. An occipito-mental X-ray will reveal the displacement.



Fig. 180. The lines of separation commonly found in fractures of the malar bone.

Treatment. Malar zygomatic fractures are best

reduced by a temporal approach. A small incision is made inside the temporal hair line, and dissection carried through to the temporal fascia. The fascia is incised revealing the muscle fibres. A strong elevator is passed down between the muscle and fascia and is guided to the deep surface of the malar. Leverage is applied and the fracture reduces with a click. Re-displacement does not frequently occur. The temporal scalp wound is closed with a few sutures. Further trauma during the period of consolidation must be avoided.

(B) **Malar Maxillary Fractures.** A severe lateral blow on the face may drive the malar bone into the antrum, comminuting the anterior wall and the floor of the orbit (see Fig. 181). The loss of orbital support results in depression of the eye and diplopia. There is marked flattening of the cheek, anæsthesia over the distribution of the infra-orbital nerve and the antrum fills with blood. There may be a related fracture of the alveolar process or the tuberosity of the maxilla. Early accurate reduction is necessary if serious functional disorders are to be avoided.

Treatment. An incision is made in the upper buccal sulcus and the soft tissues reflected from the antral wall. A fracture line is usually apparent and through this the antrum is approached. Blood and clot are gently washed out and an elevator or the finger introduced to restore the main fragments. A wide bore rubber tube is placed with its upper end in the antero-lateral angle of the antrum and a length of ribbon gauze soaked in paraffin-flavine or Whitehead's varnish is carefully packed in round the tube until the pupil level is slightly over-corrected and the malar is restored to its normal position Final adjustments to the malar can be done through the tube with a narrow elevator.

The tube and packing are left in for ten to fourteen days. Following removal, antral washouts are given daily until the wound closes. Strict attention to oral hygiene is necessary.

In some cases a combined temporal and intra-oral approach is made, so that leverage from above may assist in maintaining the position of the malar while the antrum is being packed.

Maxillary Fractures

These are essentially central facial fractures and are produced by direct violence from in front. There are two main types : firstly, the horizontal supra-alveolar fractures, including Guerin's fracture, and, secondly, the fractures of the body of the maxilla. In Guerin's fracture the upper alveolus and hard palate are separated from the superstructure, and either impacted backwards into the antra or remain loose (" floating maxilla "). Other alveolar fractures consist

of separation of portions of the tooth-bearing ridge ; and these may or may not be associated with malar maxillary displacements.

Fractures of the body of the maxilla are usually bilateral, and the whole maxillary complex is driven down and back, impacting between the malar bones on either side. The posterior attachments to the pterygoid processes of the sphenoids are comminuted and impacted and the displaced bony mass is often firmly wedged in

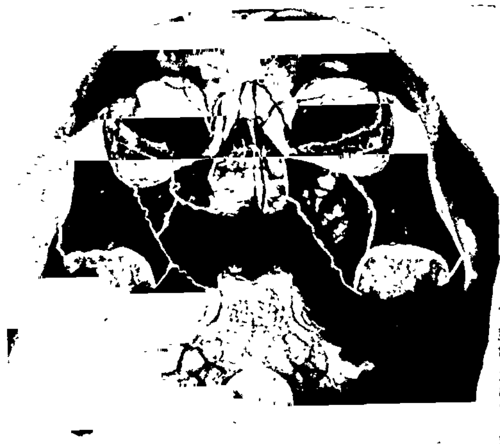


Fig. 181. Composite diagram of nasal and maxillary fracture lines. Any combination of these fractures may be found.

between the malar bones and the skull base. Nasal fractures frequently co-exist.

Any combination of these injuries, together with malar zygomatic fractures, may be found ; but [illegible] of the three primary regions [illegible] the puzzle.

Clinical Picture. The degree of shock is variable but seldom severe. The possibility of skull vault and base factures as well as cervical spine injuries should be remembered. There is very marked facial swelling and *tense œdema* of the eyelids. Irregularities in nasal and cheek contours are palpable, if not visible, and there may

be epistaxis and cerebro-spinal rhinorrhœa. The nasal airway is impeded, and blockage may be complete Loss of orbital support causes depression of the eye and diplopia. If the fracture lines pass through the infra-orbital foramina there will be anæsthesia over the area supplied by the infra-orbital nerve. Dental occlusion is abnormal, the usual deformity being an "open bite" as the depressed upper molars impinge on their fellows in the lower jaw preventing closure of the anterior teeth.

Treatment. In all fractures affecting alignment of teeth competent dental aid should be sought.



FIG. 182. Typical appearance due to œdema associated with maxillary fractures.



FIG. 183. Illustrating a convenient method of suspending a maxillary fracture to the skull. The wires, fixed to the head-cap by rubber bands to produce gradual elevation, are attached to hooks soldered to the metal dental cap-splints.

(A) Disimpaction of the maxilla is effected by inserting one blade of a Walsham forceps into the nose and the other into the mouth and gently rocking the whole mass forward. This manœuvre can also be made by grasping the alveolus in bone-holding forceps. Splintage should make use of the most convenient fixed bony point which is the skull. Metal cap splints are made to fit the teeth and a stainless steel wire passed from a hook on each side of the splint, up through the buccal sulcus and soft tissues of the cheek, to emerge below the malar prominence These wires are then attached to metal projections set into a plaster headcap. If metal cap splints are not available, dental arch wires should be wired to the teeth, and the jaws closed by wire or rubber band inter-maxillary fixation.

The cheek wires are fixed to the lugs on the lower arch wire in the pre-molar region, and so fixation to the skull is obtained. The associated fractures of the nasal and malar regions should then be reduced and splinted. The fixation of the maxilla provides a stable platform on which these secondary reductions can be based.

(B) Alveolar Fractures. The treatment of these fractures is primarily a dental problem. In cases where the fragment impacts into the antra, surgical reduction may be necessary ; and this is done as described under fractures of the body of the maxilla.

Dental treatment will consist in wiring the jaws together with fine stainless steel wire, 0·35 mm., or brass wire, 0·5 mm. If laboratory methods are available, cast metal cap splints can be made to

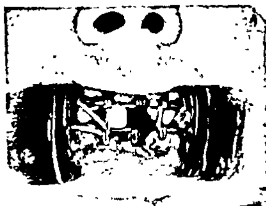


Fig. 184. Dental arch-wires wired to the teeth of either jaw provide a series of hooks which can be used for inter-maxillary rubber band fixation or inter-maxillary wiring.

fit the teeth, and the two jaws are drawn into occlusion by fastening the splints together with rubber bands. When the correct bite is obtained, the splints are locked together by a metal key and the rubber bands removed. If the fragment is very mobile the jaws should be fixed to a plaster skull cap as described above.

2. FRACTURES OF THE MANDIBLE

Anatomical Features. The mandible consists of a horizontal horse-shoe-shaped body and two vertical rami. At the junction of the body and the ramus is the angle. The ramus has two processes, the condylar which articulates with the temporal bone, and the coronoid, into which is inserted the powerful temporalis muscle.

The alveolar process of the body is the tooth-bearing region and absorbs after extraction of the teeth This fact accounts for the diminution in size and strength of the bone when it becomes edentulous. The mandibular canal passes through the substance of the bone, carrying the inferior dental vessels and nerve.

Fracture Sites in the Mandible. For the purposes of description, fractures of the mandible can be divided into the following regions.

1. Condylar process.
2. Ramus.
3. Angles.
4. Body.
5. Alveolus.

Fractures of the Condylar Process

These are either transverse or oblique and may be bilateral. They are due to force transmitted through the bone from blows on



Fig. 185. Fracture of the condylar process of the mandible.

the chin, and may or may not involve a dislocation of the temporo-mandibular joint. Diagnosis is made by palpation of the head of the condyle which fails to move as the jaw opens, and there is pain and tenderness in the pre-auricular region. Postero-anterior and 30° lateral X-rays will demonstrate the fracture. In the oblique and bilateral fractures the " bite " is disturbed. In the former the jaw moves over to the injured side and may prop open on the molar teeth. In the latter shortening occurs in both rami and results in a true " open bite "—a serious deformity.

Treatment. Where there is no derangement of the bite no special treatment is required except rest and a soft diet for a week or ten days. In cases where there is displacement of the jaw and an open bite the teeth should be wired or splinted together in normal occlusion for a fortnight, and a careful watch kept thereafter to ensure that displacement does not recur. External methods of fixation such as the chin sling or barrel bandage are without value in treatment except for first aid purposes.

Fractures of the Ramus

These are caused by direct blows on the cheek and often result in some comminution. There is little tendency to displacement



Fig. 186. Fracture in the region of the angle of the mandible.

owing to the splinting effect of the masseter and internal pterygoid muscles. Treatment is as for condylar fractures, and splintage is necessary only if there is displacement.

Fractures of the Angle

Caused usually by direct blows, they are sometimes secondary to violence applied to the chin or the opposite side of the mandible and are then associated with fractures elsewhere. In these fractures it is necessary to consider the displacement of both fragments in order that alignment of both can be restored. The common displacement of the posterior fragment is upwards and inwards. This is due to the pull of the temporalis and internal pterygoid muscles, the adducted position being due to greater power of the internal pterygoid as compared with the masseter.

Treatment. Minor degrees of displacement of the posterior fragment can be ignored. If the anterior fragment is immobilised in correct occlusion, union will take place and result in satisfactory function.

More marked displacements of the posterior fragment demand reduction and splintage. In these cases both fragments should be accurately reduced and immobilised until union is sound.

The anterior fragment, which consists of the body and opposite ramus, is reduced into normal occlusion and maintained by metal cap splints designed to fit the teeth of each jaw. These splints are wired together or are locked by a metal key. Adequate splintage may be obtained by wiring a dental arch wire to the teeth in each jaw and subsequently wiring the arches together. Strong rubber bands can be used instead of wires for the intermaxillary fixation.

The anterior fragment having been controlled, an incision is now made at the angle of the mandible, care being taken to avoid the lower branch of the facial nerve. The fracture site is exposed and the displacement is corrected. Two drill holes are made in each fragment, and a 0·35 mm. soft stainless steel wire is passed through as a figure of eight and then tightened. This will be found to hold the bone ends closely in apposition.

Fixation should be maintained for three to four weeks, at which time union is to be expected. A more elaborate method for splinting this fracture is by the use of modified Roger Anderson pins. These pins are drilled into the ramus and are connected by a locking device to a metal bar which is fixed to the cap splints on the anterior fragment This method needs specialised technique and equipment.

Fractures of the Body of the Mandible

These are usually the result of direct violence, and may occur at any site They may be bilateral or may be associated with condylar or angle fractures. Displacement will depend upon the amount of violence and upon the fracture site. Many of these fractures are linear and do not tend to displace at all, splintage being provided by the adjacent soft tissues.

Teeth in the Fracture Line. Where there are sufficient teeth on both fragments for the purposes of fixation, teeth in the fracture line should be removed. Extraction may be delayed if the added trauma will complicate the fracture or result in further loss of bone. Teeth left in the line of fracture should be carefully watched and removed at the first sign of sepsis

Treatment. Reduction and splintage should be carried out as an immediate procedure. Splintage may be by metal cap splints, dental arch wire or eyelet wiring In all cases dental co-operation



FIG. 187. Fracture of the body of the mandible with displacement.

should be sought. Only in the undisplaced linear fractures is the barrel bandage or chin sling permissible.

Alveolar Fractures

Comminution of the alveolus is associated with fractures of the teeth. It results in a mass of crushed bone containing tooth roots with exposed pulps. Infection readily occurs, and the alveolar fragments and teeth should be removed as soon as possible.

The Edentulous Mandible

Fractures of the edentulous mandible present many problems in treatment. Minor degrees of displacements may not warrant fixation, as the deformity can be overcome by remodelling the denture. The simplest method of treatment is to wire the patient's own denture on to the mandible by means of three steel wires passed round the body of the bone and twisted over the denture. If a denture is not available a metal or vulcanite trough should be made and filled with gutta-percha. This lined trough is wired on in place of the denture. The modified Roger Anderson pin fixation method may be used in these cases, or direct wiring by the figure-of-eight method described above is sometimes indicated.

Gunshot Wounds of the Face

The essential features of this type of injury are soft tissue disruption and bony loss or comminution. The key to the emergency surgery in these cases is conservatism. No tissue should be sacrificed

unless its blood supply has been cut off. In the soft tissue lesion every effort should be made to accomplish complete wound toilette without doing a formal excision of the wound. Frayed edges and crushed or shredded tissue should be removed. This should be followed by accurate layer to layer suture and the provision of dependent drainage. In cases of tissue loss, complete epithelialisation should be obtained by the use of skin grafts or flaps, or by sewing skin to mucosa round the edges of full thickness cheek, lip or nose defects. This greatly facilitates subsequent plastic repair. In grossly comminuted fractures, as many bone fragments as possible should be saved. It is permissible to remove bone only if it is devoid of periosteal attachments. The problems of splintage in these cases demand considerable ingenuity; and accurate reduction of the main bony fragments should be the primary object of treatment.

FURTHER READING

Ivy and Curtis. "Fractures of the Jaws." Lippincott, Philadelphia, 1938.
Fry, Shepherd, McLeod, and Parfitt. "The Dental Treatment of Maxillo-facial Fractures." Oxford Med. Pub., 1942.

CHAPTER XVII

FRACTURES AND FRACTURE DISLOCATIONS OF THE SPINE

Surgical anatomy

Considered mechanically, the vertebral column must be regarded as consisting of two parts. First, a supporting column of alternate layers of comparatively rigid material (the vertebral bodies) and more elastic layers (the intervertebral discs) thus combining strength and flexibility, which supports the second portion, the protective part of the column, the neural arch. This functions as a sheath for the spinal cord and also carries the articular processes which cover the one weakness of the spinal column, that of horizontal displacement, by interlocking with each other. Attached to the neural arch are the spinous processes, which serve to limit extension by their bulk, and to limit flexion by the tension in the interspinous ligaments. Further strength is added by numerous short ligaments around the neural arches and the long anterior and posterior longitudinal ligaments attached to the vertebral bodies.

To add further elasticity to the column it possesses four curves :

1. Dorsal curve.
2. Sacral curve.

} Primary. Due to alteration in thickness of the vertebral bodies.

3. Cervical curve.
4. Lumbar curve.

} Secondary. Due to adaptation to the upright position.

It is to be noted that it is the secondary adaptive curves which are most susceptible to injury, and particularly at their junction with the primary curves.

Cervical spine. The first and second vertebræ being of unusual structure, have fractures peculiar to themselves. The rest of the cervical spine is characterised by having curved cervical bodies which resist lateral force, and oblique articular facets, which are not deep, and so allow dislocation by overriding of one facet on another. The spinous processes are short and attached to the strong ligamentum nuchæ.

Movements. Flexion and extension of the head. At atlanto-occipital junction.
Rotation of the head. At the atlanto-axoid junction.

Both these movements are supplemented by small movements of the vertebræ on one another which summated allow considerable mobility. This is best seen in the movements of flexion and extension of the spine and of lateral bending.

Dorsal spine. This portion of the column is much more fixed, chiefly by the attachment of the ribs, but supplemented by the oblique nature of the articular facets, which above, look postero-laterally and below, antero-medially. The oblique nature of the spinous processes also adds a bar to antero-posterior displacement, and generally increases the rigidity.

Lumbar spine. Increased movement here, where the weight borne by the column is increasing, demands greater strength, which is achieved by the increase in size of the vertebræ and greater ligamentous thickness. The

unless its blood supply has been cut off. In the soft tissue lesion every effort should be made to accomplish complete wound toilette without doing a formal excision of the wound. Frayed edges and crushed or shredded tissue should be removed. This should be followed by accurate layer to layer suture and the provision of dependent drainage. In cases of tissue loss, complete epithelialisation should be obtained by the use of skin grafts or flaps, or by sewing skin to mucosa round the edges of full thickness cheek, lip or nose defects. This greatly facilitates subsequent plastic repair. In grossly comminuted fractures, as many bone fragments as possible should be saved. It is permissible to remove bone only if it is devoid of periosteal attachments. The problems of splintage in these cases demand considerable ingenuity ; and accurate reduction of the main bony fragments should be the primary object of treatment.

FURTHER READING

Ivy and Curtis. "Fractures of the Jaws." Lippincott, Philadelphia, 1938.
Fry, Shepherd, McLeod, and Parfitt. "The Dental Treatment of Maxillo-facial Fractures." Oxford Med. Pub., 1942.

direct injury to anything but the processes. A spinous or transverse process may be broken off. Direct injury from projectiles can on the other hand produce the most severe injuries met with.

Indirect injury. 1. COMPRESSION. Produced by falls from a height on to the feet. It may be accompanied by calcaneal fracture. Diving into shallow water produces the same effect. Produces a wedging of the bodies rather than a fracture, and is commonly combined with flexion.

2. FLEXION. May be produced in a variety of ways, *e.g.*, a weight falling on to the bent back. It produces a compression of the vertebral body, which may result in a wedge-shaped deformity, or a fracture of the anterior upper lip of the body. If the force is continued there may be a dislocation, or gross comminution of a body.

3. EXTENSION. Produced by the falling body landing with the small of the back across some raised object. This may produce extrusion of the nucleus pulposus anteriorly, or crushing injuries to the spines and laminæ.

4. LATERAL FLEXION. In the cervical region, if combined with some rotation, it may produce a dislocation. In the lumbar region it produces compression of one side of a vertebral body and scoliosis.

5. ROTATION. This may be combined with lateral flexion or flexion and may be responsible for fractures of the articular processes, laminæ and pedicles.

FIRST AID. In fractures of the cervical spine hyper-extension is to be aimed at as in other regions, and here the supine position with sandbags to check rotation is much better than the prone position, which is usually indiscriminately prescribed for fractured spines. In fractures elsewhere the prone position on the stretcher is best, not because it in itself is of much benefit to the patient, but in lifting the patient there is no danger of the acute spinal flexion which may occur in a supine case carelessly lifted by the feet and head. In gunshot wounds in which the vertebral bodies are destroyed, the patient should be carried supine. First-aid classes need more instruction about the varieties of spinal injury.

FRACTURES AND DISLOCATIONS OF THE ATLAS AND AXIS

These rare lesions achieve importance because of the danger to life from medullary compression by the odontoid process. Cases which arise from trauma, and are suitable for treatment, are rare. Recently a series of cases from minor trauma, following inflammatory lesions in the vicinity of the tonsils and pharynx, have been reported In these it is [illegible] the [illegible] the [illegible], which weakens the attachments of the transverse ligament, and

thoraco-dorsal junction is the region most commonly injured. The spinous processes are short and strong, and the articular facets deep, and look medially, so that the facets of one vertebra clasp the facets of the vertebra above. These are increased in depth, which makes dislocation a rarity, as it requires great displacement.

The intervertebral discs consist of a fluid nucleus pulposus, surrounded by a fibrous ring (annulus fibrosus) which is attached by cartilage to the upper and lower surfaces of the vertebral body. This cartilage disc is not separated from the cancellous bone of the body by a layer of compact bone, but comes into intimate relationship with the circulation in the cancellous bone. By diffusion through the cartilage the avascular nucleus pulposus is nourished. The posterior longitudinal ligament is very rarely torn owing to its strength, and it depends mainly on this fact, together with the interlocking articular



FIG. 188 Lateral view of a lumbar vertebra showing the thinning of trabecular structure at the anterior margin of the vertebra

processes, that the spinal cord is rarely damaged, and reduction by hyper-extension so safe and satisfactory.

The bony architecture of a vertebra shows it to consist of cancellous bone covered by a layer of compact bone which is very thin. The compact bone is increased in strength posteriorly in the region of the pedicles and in the laminæ. The cancellous bone of the body is weakest at the centre and the anterior margin of the body, which tends to allow easy compression of the body by the vertebra above, hinged on the articular facets behind.

Fractures of the spine lend themselves less to ordered treatment than fractures of the skull. It is impossible to discuss fractures and fracture dislocations separately, and so they will be handled together. Injury to the cord overshadows the bony injury, but the bony injury is nevertheless important, and much more so than in the skull. The discussion of the neurological phenomena in cases of fractured spine must be limited to a brief outline.

Ætiology

Direct injury. Owing to the protection of the spine by muscles, and its depth from the surface, little damage is usually done by

Axis. In a similar way the axis may be fractured at the junction of the pedicles and the body. Fracture of the odontoid at its base allows the atlas to slip forward on the axis, producing medullary compression in the same way as rupture of the transverse ligament.

Diagnosis. If the patient survives, the symptoms are similar to those of lesions of the cervical spine below this level. Displacement of bony points and loss of movement should not be tested for owing to the attendant risks. X-ray examination is made with all care, the lateral picture being taken in the ordinary manner, and the A.P. picture with the mouth open, and the central ray in line with the base of the occiput and upper incisors. The patient will be found to hold the head in the hands, and be extremely reluctant to allow anyone else to do so. Pain and stiffness are always present, and there may be symptoms of nerve pressure or paralysis of varying types.

Treatment. Immobilisation in plaster without anæsthesia, in the slightly hyper-extended position, the plaster including the forehead and occiput and going down to the xiphisternum.

Dislocations. Rotary dislocation of the atlas on the axis is the most common lesion met with, but this is rare enough. A subluxation of the atlanto-epistrophic joint with spontaneous reposition may occur more frequently and pass undiagnosed. The lesion illustrated (Fig. 217) shows a lateral shift of the atlas on the axis, combined with some forward movement of the atlas, due to relaxation of the transverse ligament of the atlas following inflammation in the region.

The more sudden dislocations usually produce sudden death.

Treatment. The maintenance of complete reduction in these cases is not always easy, though reduction by manipulation is simple. Retention may be by light traction of 7 to 14 lb. depending on the weight of the patient, which can be conveniently applied by the Crile head tractor, a simple apparatus which obtains a firm but comfortable grip, or by skeletal traction (Fig. 201). A plaster as described for fracture in this region is perhaps more satisfactory, as any possibility of gross redisplacement when moving is ruled out.

FRACTURES, DISLOCATIONS, AND FRACTURE DISLOCATIONS OF THE CERVICAL SPINE

Fractures. 1. Fractures of articular facets, and transverse processes

2. Fractures of the neural arch (Fig. 190).
   (*a*) At pedicle.
   (*b*) Behind articular facets.
3. Compression fractures of vertebral body. These are essentially

dislocation readily occurs from minor strains, such as moving the head roughly in the preparation for tonsillectomy. Such cases followed by serious results may be among the most distressing met with.

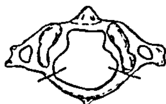


Fig. 189. The common fracture site in the atlas, through the grooves for the vertebral artery.

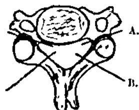


Fig. 190. The common fracture sites in the axis. A. At the pedicle. B. Through the lamina.

Fractures. Atlas. The two lateral masses are united by two comparatively weak arches. The junction of the posterior arch with these is still further weakened by the groove for the vertebral artery, and fracture may occur here from hyper-extension of the spine (Fig 189).

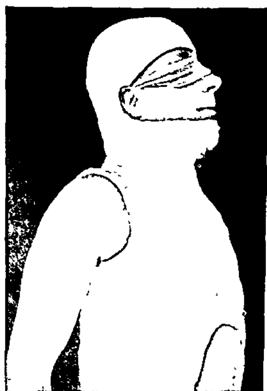


Fig. 191. The complete plaster applied for fracture of the upper cervical vertebræ. Absolute immobility is obtained by the grip on the chin, the occiput and the frontal region.

of the vertebra above and the posterior aspect of the vertebral body below. A story of injury, followed by stiff neck, and possibly a wry neck, is common to all cases, the more particular symptoms depending on whether the condition is unilateral or bilateral.

UNILATERAL LESIONS. The head is rotated away from the side of the lesion. If complete it is inclined to the side of the lesion; if incomplete, *i.e.*, the articular facets are still riding on one another,



FIG. 196. Fracture dislocation of the cervical vertebræ between C 5 and C 6. Note: anterior margin of C. 6 carried forward, inevitable paraplegia and partial paralysis of the arms.



FIG. 197. Reduction under skeletal traction.



FIG. 198. Skeletal traction relaxed.

the inclination is to the opposite side, but this is small, and in practice is obscured by the rotation. Pain is referred along a single nerve root Displacement of spinous processes or transverse processes may be detected by palpation.

The chief problem in differential diagnosis is that of acute wry neck with which the patient may associate some minor injury. X-rays will distinguish. In the radiograph a loss of the normal anterior convexity of the cervical spine must be sought for. This may even become concave.

BILATERAL LESIONS The head is pushed forward, and fixed in the midline, and there is a complete loss of rotation. Pain and paralysis from a spinal nerve lesion may be bilateral. The

similar to those in the lumbar spine, and are not discussed separately (p. 265).

4. Fracture of anterior margin of the body with fracture of the neural arch, articular facets or dislocation.

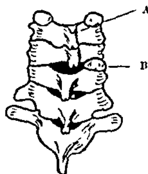


Fig. 192. Unilateral dislocation of the cervical vertebræ, viewed from behind. A. Upper cervical vertebræ rotating the head to the opposite side to the lesion B. Single upper articular facet, visible from the posterior aspect.

5. Fissure fractures of the body, without compression.

6. Fractures of the spinous processes (see p. 262).

Dislocations. 1. Unilateral. Due to flexion plus some rotation, or violent lateral flexion. The articular process of the vertebra above slides over the facet below, and catches in the neural groove.

2. Bilateral. Due to severe flexion. Both articular facets are displaced forwards into the neural grooves of the vertebra below.

These are most common in the region of C. 4, 5, and 6. The ligaments of the articulation and the intervertebral disc are always torn, and a chip fracture of the vertebral body below that dislocated is commonly associated with them (Fig. 196).

Symptoms. The minor fractures with no dislocation give a history of injury associated with persistent stiff neck and the injury is only diagnosed by radiography.

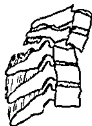


Fig. 193. Lateral view of a bilateral fracture dislocation of the cervical spine.

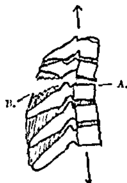


Fig. 194. The same spine under traction as indicated by the arrows. A Ruptured intervertebral disc. B Torn interspinous and interlaminar ligaments



Fig. 195. The same case reduced. Compare with radiographs, Fig. 196.

The more severe fractures gain their significance as a rule from the accompanying dislocation, which is responsible for the signs of pressure on the cord and which vary from complete paralysis to a transitory monoplegia. The cord is pressed between the neural arch

applied in a number of ways. In all cases a sloping bed is used and the patient's weight used as counter-traction. Traction on the head may be made by a halter under the chin and occiput, or small trephine holes have been made in the outer table of the skull under local anæsthesia and an adjustable metal tractor caught under the outer table, and pull made from here. In either case the sling is attached to weights passing over a pulley, at the head of the bed. These are steadily increased, if necessary, up to about 40 lb. The neck can be under radiological control, and it will be seen to slowly relax (Fig. 197) till the facets disengage and slide over one another. This can be appreciated by the fingers if they are kept on the transverse processes of the vertebræ involved. Where the pulley and weights are not available the sling can be attached to a belt around the waist of the surgeon, who holds the head in his hands and, by leaning back, produces an increasing amount of extension, and can, if necessary, manipulate the neck. Another method of obtaining a graduated pull is by a pulley block and a spring balance. Reduction can be carried out under local anæsthesia as the time taken varies from two to fifteen minutes, rarely longer. If necessary gas with a little ether can be given, or pentothal sodium used, but this increases the need for care and accurate radiological control.

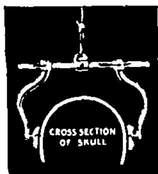
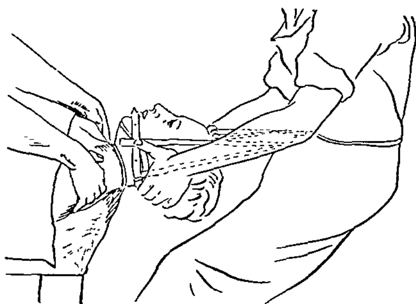


Fig. 201. The technique of skeletal traction on the skull. The metal hooks penetrate the outer table of the skull only.


Fig 202. Illustrating the method of obtaining traction on the neck by a head halter attached to a belt around the surgeon's waist. Both hands are left free for manipulation and control.

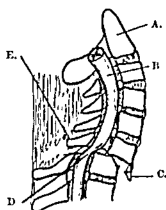


Fig. 199. Illustrating the mode of damage to the spinal cord in fracture dislocations of the cervical vertebræ. A. Dens. B. Spinal cord C. Chip fracture of the body of the sixth cervical vertebra, with rupture of the nucleus pulposus D. Cord nipped between the laminæ of the vertebra above, and the body of the vertebra below. E. Torn ligamentum nuchæ and interspinous ligaments (Compare Fig 196)

deformity of the depressed spinous process is more obvious, and cord symptoms are more likely.

Fracture dislocations. The fractures commonly associated with dislocations are fractures of the spinous processes, fractures of the articular facets, and chip fractures of the type shown in Fig. 199, and compression fractures of the vertebral body.

Treatment. Reduction as soon as possible, either with no anæsthesia or local anæsthesia, or, as a last resort, with general anæsthesia. The necessity for anæsthesia depends to some extent on the method, and methods in which it is unnecessary are to be favoured, owing to the risk of manipulation in a toneless unconscious patient.

1. *Manipulation by hand.* This is suitable for incomplete and complete unilateral lesions. With the head over the end of the table and held in the operator's hands, it is gently extended, then flexed to the opposite side to the lesion, and after further extension rotated to the side of the lesion, when the facets should ride over one another. (Fig. 200).

2. *Reduction by traction.* Slow reduction by traction over a period of hours or longer has been abandoned, but fairly rapid reduction by traction has become the favoured method. It may be



Fig. 200 The manual method of reducing dislocation of the cervical vertebræ. Counter-traction and steadying force is applied by the hands on the shoulders.

applied in a number of ways. In all cases a sloping bed is used and the patient's weight used as counter-traction. Traction on the head may be made by a halter under the chin and occiput, or small trephine holes have been made in the outer table of the skull under local anæsthesia and an adjustable metal tractor caught under the outer table, and pull made from here. In either case the sling is attached to weights passing over a pulley, at the head of the bed. These are steadily increased, if necessary, up to about 40 lb. The neck can be under radiological control, and it will be seen to slowly relax (Fig. 197) till the facets disengage and slide over one another. This can be appreciated by the fingers if they are kept on the transverse processes of the vertebræ involved. Where the pulley and weights are not available the sling can be attached to a belt around the waist of the surgeon, who holds the head in his hands and, by leaning back, produces an increasing amount of extension, and can, if necessary, manipulate the neck. Another method of obtaining a graduated pull is by a pulley block and a spring balance. Reduction can be carried out under local anæsthesia as the time taken varies from two to fifteen minutes, rarely longer. If necessary gas with a little ether can be given, or pentothal sodium used, but this increases the need for care and accurate radiological control.



FIG. 201. The technique of skeletal traction on the skull. *The metal hooks penetrate the outer table of the skull only.*

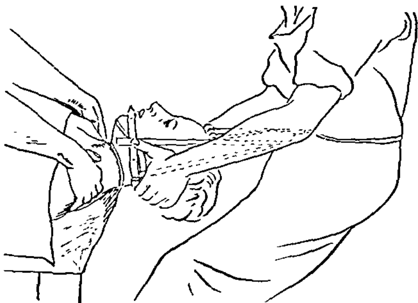


FIG. 202. Illustrating the method of obtaining traction on the neck by a head halter attached to a belt around the surgeon's waist. Both hands are left free for manipulation and control.



Fig. 203. Anteroposterior film showing unilateral dislocation on the left side of the articulation between the seventh and first cervical vertebræ.



Fig 204 Forward dislocation of the seventh cervical vertebra on the first dorsal. Note the apparently excessively large foramen for the nerve, due to the riding up of the articular process. The accompanying fracture of the spinous process of C.6 is not clearly shown.



Fig. 205. Compression fracture of a dorsal vertebra (D.7) showing the wedging of the vertebra.



Fig. 206. Film showing an accessory centre for the anterior margin of the fifth lumbar vertebra Sometimes mistaken for a fracture.

Retention. After satisfactory control X-rays, a plaster jacket with the head in hyper-extension is applied, which extends from the xiphisternum to the occiput and chin, which are held much on

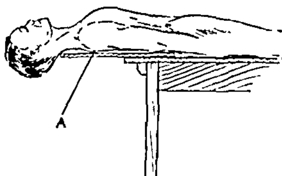


Fig. 207. Diagrammatic representation of the method of applying a plaster in fractures of the cervical spine. The patient's head hangs over a thin wooden lath (A) attached to the table, and is supported in the hands of a seated assistant.

the same plane. The method of application is shown in Fig. 207. The patient is laid flat on an ordinary wooden table to which a thin wooden lath has been nailed, so that his head hangs extended over the end of the lath and supported by an assistant. With his hands placed on the sides of the table a plaster jacket can be applied to the neck and upper part of the thorax. When this has set the

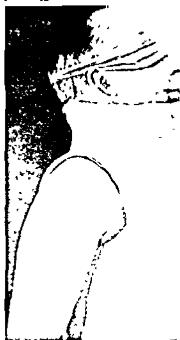


Fig. 208. Plaster jacket with cervical extension for fractures of the lower cervical region.

patient may be slipped upwards off the lath, which being padded slides out readily, and the rest of the jacket completed.

Recurrence of displacement after reduction of a dislocation should raise, first, the question whether reduction was complete, and, second, the suspicion that an articular process may be fractured, thus allowing recurrence. Such cases should be treated by continuous skeletal traction, while lying on a modified plaster bed, including the thorax and neck.

Osteoarthritis of the cervical spine. This common complaint, by increasing the rigidity of the cervical spine also increases its liability to fracture. This takes two forms :

(*a*) Minor fractures of a process, or separation of an osteophyte. This produces the features of an acute stiff neck and has often to be considered in the differential diagnosis of spinal injuries in the elderly. It can only be excluded by good radiography, sometimes oblique views being needed.

(*b*) More severe fracture-dislocations or dislocations, which are accompanied by variable cord injury.

In osteoarthritic spines hyperextension of the spine plays a greater part in the production of injuries than in the mobile spine. Indeed rigidity of the spine is a prerequisite of extension injury.

FRACTURES OF THE DORSAL SPINE

This region is so protected and supported by the ribs that the only fracture commonly met with is a compression fracture of the vertebral body. This remark of course excepts the last two thoracic vertebræ which with the upper lumbar vertebræ are the vertebræ most commonly injured. It is perhaps owing to the support of the ribs that compression fractures of this region are often unrecognised on first appearance. A small kyphos may pass unnoticed and it takes a few days in the upright position before the vertebral body is further collapsed by the weight of the body. This difficulty is also noted in the lumbar region. It is highly probable that all cases of Kummel's disease are overlooked cases of compression fracture, and not due to any post-traumatic vascular pathology in an unfractured vertebra.



FIG. 209. Method of forcible reduction of compression fractures of the upper dorsal spine, by hyper-extension over the edge of the table.

The symptomatology, diagnosis and treatment will be discussed with fractures of the lumbar spine, which it closely resembles. It must be mentioned that the same features which render injury to the dorsal spine

so uncommon also render its reduction difficult. *It is impossible to* get the leverage on the thoracic spine that one can get on the lumbar, and so it is difficult to reduce a compression fracture so satisfactorily. Complete reduction is, on the other hand, not so important. This is vouched for by the number of cases in which a sound functional result is seen in association with moderate wedging of several vertebræ, or *marked* wedging of one vertebral body. The difficulty in reduction combined with the wish to relieve the patient of a long stay in a *plaster* jacket, has encouraged the more casual treatment of these injuries, and this has not been followed by any rise in post-traumatic disability. It is therefore better to treat moderately severe injuries of the thoracic spine by a period of bed rest, followed by bed exercises, and to allow the patient to get up when pain-free. In fractures of the lower dorsal spine (T.9–T12), the case is judged on its merits.



FIG. 210 Flexion fracture of the lumbar spine showing the fracture of the spinous process which may replace ligamentous rupture (Compare Fig. 211)

If reduction is to be attempted, hyperextension of the spine over the edge of a table is much more likely to be effective than the sling recommended for lumbar fractures (Fig. 209). If an anæsthetic is needed to relieve pain, the application of the jacket is postponed till the patient has recovered, as the comatose patient is difficult to handle except by the longitudinal sling method, in which the patient is lying prone in a long towelling or canvas sling.

The most interesting complication of fractures of the dorsal spine is fracture of the body of the sternum, and the occurrence of such a fracture and, particularly, if it does not reduce itself spontaneously, should at once direct attention to the vertebral column (Fig. 241)

FRACTURES OF THE LUMBAR SPINE

The first lumbar vertebra lies at the junction of the more rigid dorsal spine with the flexible lumbar spine, to the lower end of which is attached the long lever of pelvis and legs. It is for this reason the most frequently injured vertebra, and the incidence of injury to the other vertebræ falls off as one gets away from L1. Seventy

per cent. of fractures occur in the region T10 to L1. Fifty per cent. of all fractures of the spine are compression fractures.

Mechanism. See earlier discussion on page 248.

Types of fracture. 1. Fractures of the spinous processes and

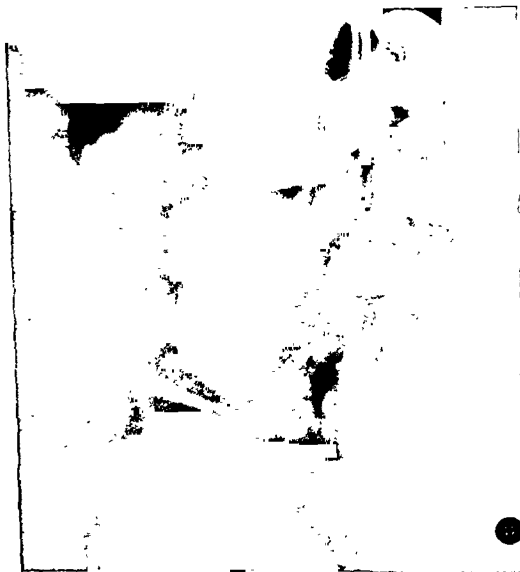


Fig 211. Fracture of the spine with rupture of the spinous processes and separation of a wedge from the vertebral body. (Compare Fig. 210.)

laminæ. (*a*) Alone , (*b*), in association with compression fractures of the body.

2. Fractures of the transverse processes.
3. Compression fractures of the vertebral bodies.
   (*a*) Fissure.
   (*b*) Compression. In A.P. plane, kyphosis (Fig. 211).
   In lateral plane, scoliosis.
   (*c*) Comminuted fractures.

4. Fracture dislocations of the vertebræ.
   (*a*) Antero-posterior.
   (*b*) Lateral.
5. Rupture and herniation of the nucleus pulposus.

Fractures of the spinous processes and laminæ. For convenience fractures of the spinous processes of the lumbar and cervical spine will be discussed together. They are uncommon and may be

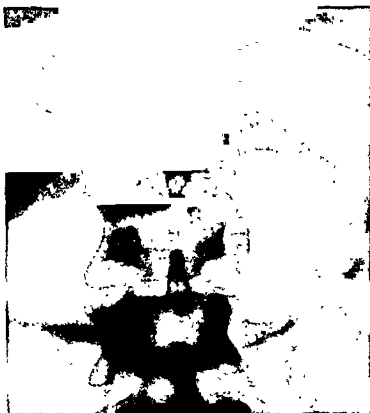


FIG. 212 Antero-posterior view of a flexion fracture of a spinous process, and laminæ and transverse process of a vertebral body. Compare Fig. 211.

due to direct violence, *e.g.*, falling on the back across a beam, or more commonly due to the pull of attached ligaments. In the cervical region the slender spines tend to fracture just below their terminal expansions, to which powerful muscles are attached. In the lumbar region in flexion fractures of the spine the separation of the neural arches may not occur through a ligamentous area, but by splitting of a spinous process, the interspinous ligaments remaining attached to its upper and lower half (Fig. 210). Owing to the increased length of the process in the upper dorsal and cervical region it is more common here.

The sixth cervical to the third thoracic spine are susceptible to fracture in workmen digging. The history given is usually that the clod of earth being thrown off the shovel sticks to it, and the patient feels a sudden stab of pain in the back, accompanying the unexpected jar. Its occupational associations has earned for this lesion the title of " shoveller's fracture."

SYMPTOMS. Local pain, bruising, tenderness and muscle spasm in the region. Some depression of the spinous process may be palpated, or it may be discovered to be movable. Where the laminæ are fractured and depressed there may be pressure on the cord, which will demand relief by open operation.

TREATMENT. Owing to the multitude of ligamentous attachments the displacement is usually small, the only necessity being the relief of pain, which may be obtained by confining the patient to bed, or more efficiently by infiltration of the area with novocaine. Three alternative lines of treatment present themselves in the cervical region.

(*a*) Massage exercises, and further infiltration with novocaine, with a Schanz collar for support.

(*b*) A light plaster jacket with cervical support.

(*c*) Excision of the tips of the fractured spinous processes.

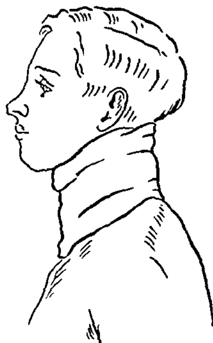


FIG. 213. Schanz collar for the immobilisation of the cervical spine in cases of minor injury.

In minor cases with one spinous process only involved the first procedure is satisfactory. Union is usually satisfactorily achieved in spite of the movement. Very rarely pain persists, and non-union establishes itself, when the fractured tip of the process must be excised. If other lesions are associated with the condition, then the light plaster cast is needed. Where there are multiple fractures with two or more spinous processes involved, there is a tendency for non-union to occur, probably due to the excessive mobility permitted, pain is apt to be troublesome and persistent. These cases, of which " clay shovellers " fracture is an example, should have excision of the fractured fragments as soon as possible.

Fractures of the laminæ tend to be bilateral, leaving the spinous process attached to the loose centre fragment. If depressed, which is uncommon and cord symptoms are present the need for operation is obvious. If not depressed they are often missed, till persistent pain, and the greater ease with which



FIG. 214 Fracture of the transverse process of the first and second lumbar vertebræ.



FIG. 215. Anterior view of a dislocation of the axis from the atlas, due to relaxation of the transverse ligament of the atlas. The X-ray of this case is shown in Fig. 217.



FIG. 216. Posterior view of same case.



FIG. 217. Anteroposterior film of the first and second cervical vertebræ, taken through the open mouth, showing subluxation of the first the second cervical vertebra. (Same case as in Figs. 215 and 2

the fracture is seen in the radiograph after a short period has elapsed, enable a diagnosis to be made. In such cases the spinous process only should be excised.

Fracture of the transverse process. The majority of these occur in the lumbar region due to direct violence, or more rarely to muscular violence from the pull of the psoas. The processes most frequently damaged are those of L2, 3, and 4, either singly or together.

SYMPTOMS. Local pain, tenderness and limitation of movements of the spine due to muscle spasm are seen. The pain may be widely distributed or resemble lumbago of the localised type. Raising the leg from the bed on the affected side, or passive hyperextension may produce pain due to pull on the ilio-psoas. A retroperitoneal hæmatoma or associated renal damage must be watched for in severe cases (Fig. 214).



FIG. 218. Ununited accessory centre for the transverse process of the first lumbar vertebra, resembling fracture.

DIAGNOSIS. This depends on the X-ray, but confusion with the features of recent fracture may arise from : 1. An ununited centre for the transverse process. This is usually bilateral, is most common in L.1, and shows a layer of cortical bone over the surfaces supposed to be the fracture line (Fig. 218). 2. Similarly an atrophic rib attached to L1 may be mistaken. 3. The line of the psoas shadow may be confusing. 4. Rarely a calcified gland occupies a position opposite the end of a transverse process.

TREATMENT. Owing to the fact that pain may persist for some time after this injury it is not to be treated lightly. Rest in bed to commence with is indicated, and, after improvement, judicious exercises and radiant heat are given.

PROGNOSIS. This is good, but a few cases develop chronic back strain which shows up after the injury is apparently healed. In some cases this is psychotic in origin, and no man with fracture of a transverse process should be told he has a fractured spine.

Compression Fractures of the Lumbar Vertebræ

These may be divided into two groups of cases :

Group. 1. In which the interspinous ligaments and intervertebral ligaments are intact. This limits the displacement, and wedging of a vertebral body is usually all that occurs ; sometimes there

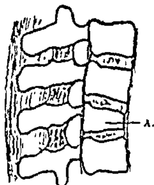


FIG. 219. Compression fracture of a vertebral body without rupture of ligaments. A. Slightly wedged vertebra.

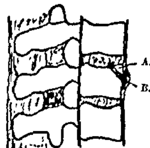


FIG. 220. 'Fracture of the upper anterior margin of a vertebra. Usually some wedging of one or other vertebræ accompanies this lesion. A. Bony chip. B. Nucleus pulposus herniating through the fissure and lying below the anterior longitudinal ligament.

is a fissure, or a chip off the body below, or the wedging may extend over several vertebræ. The intervertebral discs remain intact. Cord symptoms and nerve-root symptoms do not occur. This is the most common lesion (Fig. 219).

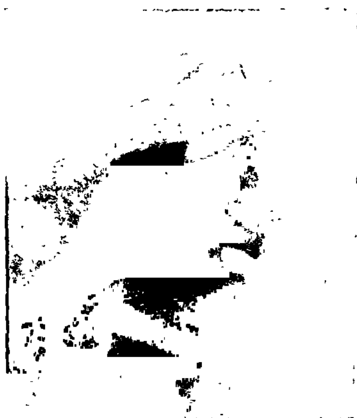


FIG. 221. Crush fracture of the twelfth dorsal and first lumbar vertebræ with marked kyphosis. No cord symptoms.

Group. 2. Where the interspinous and interlaminar ligaments are torn a much greater displacement can occur, and strain is thrown on the anterior and posterior longitudinal ligaments. The posterior ligament being very strong remains intact in all but shattering lesions, and so helps to protect the cord. The tearing of one interspinous ligament usually allows the force to be expended on completely crushing the body of the vertebra below. The nucleus pulposus may be ruptured and nuclear material is forced into the cancellous bone spaces or into the spinal canal. If the force carries the upper portion of the vertebral column still further forward there is danger of compression or even section of the cord, which is caught between the laminæ of the vertebra above and the posterior surface of the body below. It is only with injury of this type that dislocation may complicate the picture. The anterior longitudinal ligament being strong and at the centre of the angle of displacement is not torn, and is a guarantee that in correction by hyper-extension over displacement will not occur (Fig. 222).

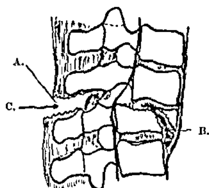


Fig. 222. Fracture of the vertebral body with rupture of the interspinous ligaments, showing the greater displacement allowed, and the increased danger of cord damage. A. Herniating nucleus pulposus. B. Ruptured interspinous ligaments. C. Site for injection of local anæsthetic.

Symptoms. Pain in the back is the most prominent feature. Even in the absence of cord injury the patient may say he feels broken in two. A kyphos may be obvious, but if the patient has been transported correctly it may not have occurred, or be partly reduced. In the severe displacements an irregularity in the level of the spinous processes may be palpated, or there may be a gap of unusual depth between them. The spine is fixed by muscle spasm. Nerve-root pain of a unilateral type or "girdle" pain may be complained of, and all the degrees of cord injury to be discussed later may be associated with the lesion.

A history of suggestive injury plus local pain justifies an X-ray. It is the lateral view which is most revealing. The antero-posterior film is often confusing, especially in the lower lumbar region where the vertebræ are on an angle.

Fracture dislocations. Most of the features of dislocation of both articular facets in the lumbar region have been discussed above, but it remains to mention a rare lateral fracture dislocation which occurs with lateral flexion alone, or combined with a lateral shifting of the body when the pelvis is fixed. The upper articular facet of one side is broken which allows the vertebra above to slip sideways,

and this may be accompanied by a lateral compression of the body of the vertebra. This is best seen in the A.P. X-ray, and if there is little displacement may be overlooked in the lateral film. A scoliosis together with many features mentioned above are found Treatment may be that of a compression fracture, extension being combined with lateral pressure. The risk of cord damage in reduction is nil, but there is a very grave risk at the time of the accident.

If paraplegia is present grave nursing difficulties will be encountered in plaster, and open operation by fixing the parts will simplify

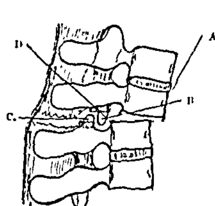


FIG. 223A. Dislocation of the lumbar vertebræ. A. Upper vertebra pushed forward. B. Lower facets riding on the laminæ of the vertebra above. C. Upper facets of vertebra below, visible at laminectomy D. Cord almost invariably damaged here.

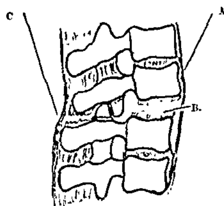


FIG. 223B. Effect of extension on a lumbar dislocation. A. Upper vertebræ are still anterior to the vertebræ below. B. Increased intervertebral space, larger than normal. C. Depression of the spinous processes still persists. The dislocation is often not recognised till this picture is seen

care of the skin. If there is no paralysis recovery will occur in spite of wide displacement (Fig. 224). This would be best avoided, and open operation again provides the best method of retention, as well as of reduction.

Dislocation of both articular facets occurs in the lower dorsal and lumbar regions In these cases, following severe hyperflexion, the articular facets of the vertebra above ride up over the superior facets of the vertebra below, and come to rest on the upper surface of the laminæ in front of them (Fig. 223A and B). It is obvious that to make them retrace their path the vertebræ must be separated for a distance equal to the depth of the articular facets, which in the lumbar region approximate to ¾ inch. This is impossible to accomplish by traction and open operation must be resorted to. Often the lesion is not recognised till control X-rays are taken after attempted hyper-extension reduction. These show a widening of the space between the vertebræ due to a hinging on the new articula-

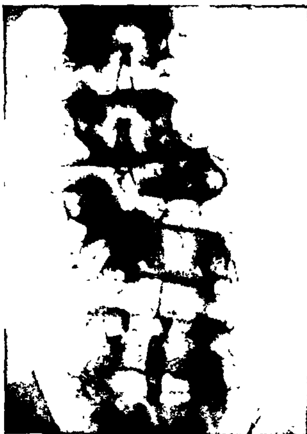


Fig. 224. Lateral dislocation of the spine, associated with hemifracture of a vertebra and laminæ. No cord symptoms.



Fig. 225. Lateral view of the same case.

tion, together with a forward shift of the upper vertebra. The lesion is almost inevitably accompanied by cord damage to a serious type, and a compression fracture of the lower vertebra.

Operative reduction. A curved incision is made over the kyphos, and the spines and laminæ exposed. The lesion is easily recognised by the uncovered glistening articular facets of the lower vertebra. *To allow reduction these must be cut away, and to* approach them it is often necessary to remove the spinous process of the vertebra above. Once cut away, reduction by elevation of the legs, as described later, is carried out. In the presence of paralysis the treatment is described on page 280. If absent a plaster jacket can be applied.

Treatment of Compression Fractures

Fractures with minimal displacement. It is unnecessary to prevent angulation by some form of spinal support, and in mild cases a period of bed rest and graded activity (*e.g.*, fractures of the dorsal spine) should be ordered. Slight wedging is consistent with good function and the patient's own feeling should be used as a guide to his activities. What he can do without pain he should be permitted to do, progressing through bed exercises, to sitting up in bed, then out of bed, walking and finally, standing exercises. If pain is complained of at any step, a return to the previous regime for a few days is needed. Patients are usually actively up and about at the end of the third week.

If for any reason bed rest cannot be given some form of fixation becomes necessary. The most convenient is a plaster jacket applied by one of the various means described below. Poroplastic or other more expensive jackets may be used. They must be worn for a *period of three to six months depending on the severity* of the accident

Fractures with displacement. It has been shown by experience that quite considerable deformities can exist in the spine, and the patient still remain very active. If the spinal column is opened up by complete reduction, a gap is left anteriorly which must fill with cancellous bone if the spine is to be solid. For this to occur much time must be spent in plaster. Any plaster is uncomfortable, and inevitably introduces more stiffness in the spine. When it is removed body weight often compresses the fracture site, thus reducing the reduction obtained. Concentration on function, by active exercises, at first recumbent and then up and about as outlined above is the best treatment for the fracture with an acceptable degree of kyphosis, in the adult.

A kyphotic deformity in a child will demand reduction and

retention in plaster. There stiffness is not to be feared. Certain gross deformities must be reduced, but these are infrequent, and often accompanied by cord symptoms, which demand other treatment.

REDUCTION. In general reduction is seldom needed, and most cases can be treated by an active regime. If reduction is to be carried out the sooner the better, once the primary shock has passed off. Local anæsthetic can be very useful, but it is amazing how many cases can be gently reduced under the influence of morphia and scopolamine, with no local anæsthesia at all. In at least 50 per cent.

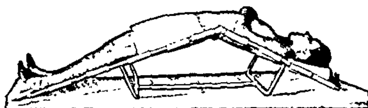


FIG. 226. One variety of hyper-extension frame as used to obtain gradual hyper-extension of the spine.

of cases any more anæsthesia than this is unnecessary. If any general anæsthesia is used pentothal followed by gas-oxygen is satisfactory. Spinal anæsthesia has been used very successfully.

Reduction by all methods depends on the leverage exerted on the fracture site by hyper-extension of the spine. That hyper-extension can be carried out safely depends on the anterior longitudinal ligament being intact, and the interlocking of the articular processes. Where these are broken or dislocated there is much greater risk of displacement. Numerous methods for extending the spine have been developed and will be outlined.

1. *Slow reduction* on a hinged frame of the Bradford type. The kyphos is arranged to lie at the level of the hinge, and the extension increased daily. This is a slow method, which is not always satisfactory, and may be very uncomfortable. It keeps the patient on his back when other methods allow him about, and is very seldom used (Fig. 226), except in the presence of complications such as paralysis, or abdominal distension.

2. *Rapid reduction by hyper-extension.* (*a*) By elevating the head and shoulders on one table, while the body lies prone with the legs resting on a lower table which comes up to the level of the lower margin of the pubes, and thus allows the lumbar spine to sag between them. After a little time has elapsed for muscular relaxation the deformity reduces itself, and a plaster jacket is applied.

(*b*) Leaving the legs strapped to the lower table, a sling may be applied around the chest below the arms, and this being attached by a pulley block to a hook high up in the wall, tightening it will still further hyper-extend the spine than method (*a*). After reduction it is wise to relax this a little as very full hyper-extension is painful for the patient and likely to produce pressure sores under the plaster or even paralytic ileus.

(c) By elevating the legs of a prone patient hyper-extension of the spine may be produced. This method is useful when accompanying operative procedures as the apparatus out of the way. It produces only a moderate hyper-extension which is satisfactory for patients with a mild injury.

(d) By laying the patient supine and strapping the legs and feet firmly to the table, so that the patient's upper thorax hangs over the end of the table,

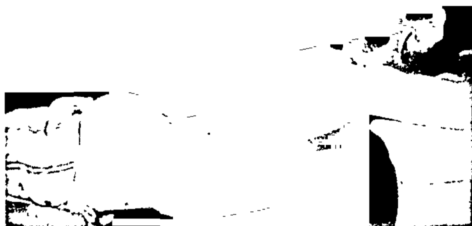


FIG. [illegible]

given a few minutes for muscular relaxation

hyper-extension of the thoracic and lumbar region may be produced. The edge of the table is placed at the level of the thoracic kyphos. As soon as the deformity is reduced to one's satisfaction the patient is slung in the manner described below, except that the webbing is placed on a level with the lower thoracic vertebræ, and a plaster jacket applied.

(e) The most satisfactory method of reducing the fracture, and of applying a jacket, is suspension with the patient lying in the supine position. This is done by hanging the patient over a tense webbing strap stretched by a wide (26 inches) steel horseshoe which can be elevated as desired by a block and tackle system attached to a hook in the ceiling. Alternatively, if a hydraulic operating table is available, fixed suspension, with the table fully elevated

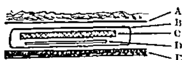


FIG. 228. The padding in the suspensory method of applying a plaster jacket Diagrammatic transverse section A. Skin. B. Layer of cellophane C. Pad of gamgee tissue 15 × 4½ inches D. Webbing band. E. Plaster of jacket.

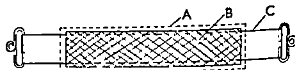


FIG. 229. Diagram of layers of material around spinal sling.—

A. Layer of cellophane.
B. Gauze pad.
C. Sling

may be used, and the table lowered to obtain hyper-extension. The webbing is held by two hooks from which it can be readily detached on releasing the patient. Between the patient and the webbing a pad of gamgee tissue 15 inches by 4½ inches is placed, and both are wrapped in cellophane. This is important as the cellophane prevents the plaster from adhering to the webbing and so enables it to be pulled out from between the padding and the plaster once this has set (Fig. 228).



Fig. 230. The method of application of a plaster jacket by the sling in the supine ...
and over ...
is adjuste...

The webbing and pad is arranged below the patient at a level corresponding to that of the fractured vertebra. The patient is then gradually elevated by hoisting on the block and tackle. After a few minutes the muscles of the spine relax and the patient sags over the webbing, thus reducing the deformity and hyper-extending the spine. The pain is controlled in all but severe fractures by morphia and scopolamine. In the more severe cases gas and oxygen is necessary, but where anæsthesia is used the patient must not be raised so high from the table to avoid over-extension of the spine, which is apt to occur if all muscle tone is lost.

A plaster jacket is applied in this position, as described in Chapter XII, allowing the webbing to protrude through gaps in either side. When the plaster has set it is withdrawn through these, the gamgee pad trimmed, and

the gaps closed with a plaster bandage. The plaster is trimmed and a window made anteriorly over the stomach. Occasionally a window posteriorly over the spinous processes at the height of the lumbar curve may be needed to relieve pressure on the tips of the spinous processes of very thin or elderly patients. The pad is left *in situ* under the posterior opening and prevents pressure on the edges of the plaster.

The hammock method. An equally comfortable method, is to sling the



Fig. 231. The plaster applied. The sling is left in position till the plaster sets, and then can be easily withdrawn, and the gaps plastered over.

patient in a hammock made of towelling face downwards. An opening is cut in the material of the hammock, for the patient's face. By adjusting the curve of the hammock the desired degree of curvature of the spine may be obtained. A plaster jacket is applied over this, and the material of the hammock cut away, as it cannot be withdrawn from the jacket.

In all cases pressure should be relieved over the spinous processes either by padding or by cutting away the plaster over the most prominent spines.

After-treatment. After the application of such a jacket the patient is very uncomfortable till he adapts himself to the new position, and requires morphia for the first twenty-four hours. Vomiting during this period is not uncommon, and should occasion no alarm unless it continues Paralytic ileus of a subacute type

may follow a plaster applied too tightly and in too great hyper-extension. This is rare, but is indicated by deterioration in the patient's condition, pain, distension and continuation of the vomiting. It necessitates removal of the plaster.

The patient should have the cast dried by being placed under a heat cradle for the first night. The back of the cast is dried first while the patient is awake and can lie in the prone position. Careful balancing of the cast is necessary for the first days, and an inexperienced nurse should be carefully instructed where pillows are to go, if the patient is to be protected from discomfort, and the plaster to remain undeformed. On the following day he is, as a rule, more comfortable sitting up or trying to walk, and when he commences this it will as a rule be found necessary to trim the plaster further, as the patient settles into it. A control X-ray should be taken through the plaster to check the reduction. If unsatisfactory the patient is allowed to adapt himself to the amount of hyper-extension obtained for a few days, and is then replastered in greater hyper-extension.



Fig. 232. The finished jacket.

As soon as convenient exercises are commenced, which are designed to use all the muscles of the body, and particularly the extensors of the spine. Those illustrated in Böhler's books are rather heroic, but it is remarkable what a patient can do. These are continued throughout the period of immobilisation which varies according to the severity of the fracture from three to eight months. A renewal of the plaster is usually necessary at the end of the second month, and the opportunity is taken for a control X-ray without the plaster. The chief features sought for in this are the absence of collapse and kyphosis, and the building up of an evenly dense and solid vertebral body. At this period a poroplastic jacket may be fitted and this, or a new plaster jacket, is worn till the end of treatment. A final X-ray is taken at the end of treatment to see that the vertebræ are soundly healed. This is indicated by restoration of the shape and outline of the body, satisfactory density, in comparison with the other vertebræ,

and absence of nuclear prolapse. In severe cases restoration of shape is impossible, and satisfactory density and trabeculation the important points.

Injury to the nucleus pulposus. Where this occurs in fractures of the vertebral body it is neglected in the treatment. Schmorl has shown that the upper plate of the vertebral body may be ruptured and the nuclear material forced into the cancellous tissue where it may be seen in the lateral X-ray. This may produce features of injury or of back strain sufficient to require a plaster support and is characterised by severe pain, so severe in some cases as to rouse suspicions of hysteria, and decrease in the width of the intervertebral space. Diagnosis is complicated by the fact that this collapse may not occur immediately, and confirmatory radiological evidence may not be seen till a second film some days later. In a few cases prolapse may be seen immediately by loss of trabeculation centrally and the diagnosis assisted by tomography.

Peripheral rupture of the annulus fibrosus may allow immediate prolapse, or the onset of the pain and neurological features may be delayed. Prolapse may be lateral with nerve root pressure symptoms, such as sciatica or brachial "neuritis," or central with cord compression features. It is confined almost completely to the cervical and lumbar regions. Operative removal by limited laminectomy is the treatment of choice.

Complications of fracture of the spine. 1. Shock, which may be severe.

2. Hæmorrhage. Intrathecal and into the cord.

3. Dislocation, in the cervical and lumbar region only.

4. Damage to the spinal cord. (Discussed later.)

5 Subcutaneous hæmatoma. This occurs when the interspinous ligaments are ruptured, and may cause gangrene of the skin by pressure and interference with its blood supply. It should be incised and drained for forty-eight hours, and the incision then closed.

6. Retroperitoneal hæmorrhage, this increases pain and shock, and may produce a palpable mass in the loin. It is probably the chief cause of paralytic ileus.

7. Paralytic ileus. This rare complication is similar in origin to the condition which follows plastering the patient in excessive hyper-extension. The exact ætiology is uncertain, but the condition is important as it may raise the suspicion of intra-abdominal damage and be made the excuse for laparotomy. As cases with paralytic ileus are in a poor condition such an operation may be fatal, and is of no benefit to the condition. The features are a distended tympanitic abdomen, with some pain and little vomiting There may be passage of flatus, and audible borborygmi, but in severe cases there is absolute paralysis for a short period. With the treatment of the shock and rest the patient's condition generally improves, and intestinal function is restored again.

If a plaster jacket has been applied it frequently requires removal. If the condition then fails to improve, intestinal drainage by the

passage of a Ryle's tube and continuous suction must be commenced, and fluids given intravenously. On this regime distension subsides and intestinal function is slowly restored.

8. Damage to nerve roots. This may occur by direct involvement in bony fragments (rare), or more commonly by the disc prolapse described above.

9. Visceral injury (see page 292).

INJURIES TO THE SPINAL CORD ASSOCIATED WITH THE FRACTURES OF THE SPINE

It is in the fracture dislocations that sufficient movement of one vertebra on another is allowed to produce severe injury to the cord. Thus in the cases of fracture dislocation of the lumbar vertebræ, when the articular facets sit on the laminæ of the vertebra below, the cord is inevitably damaged and frequently severely. Usually, the cord is nipped between the laminæ of the vertebra above and the posterior aspect of the body below. Cord injury may be produced in other ways as outlined below.

Types of cord injury. 1. STRETCHING. Severe extension or flexion may produce a very short-lived quadriplegia with rapid recovery, if it occurs in the neck. A paraplegia of similar type seldom occurs from injury in the lumbar region as the range of movement is more limited. Later there may be some paræsthesia or muscular weakness. The X-ray will be negative in a few cases.

2. SPINAL SHOCK OR CONCUSSION. This may follow bullet wounds in the region of the cord. The paraplegia last three days to three weeks and goes on to complete recovery. The symptoms of the above types of injury tend to be less complete than the succeeding two types.

3. COMPRESSION. This may be due to a variety of causes.

(a) *Œdema.* Possibly the most frequent cause in cases which recover completely.

(b) *Pressure of a foreign body.*

(c) *Depressed fragments of bone.* Usually the spine and laminæ. Demands relief by operation.

(d) *Hæmorrhage.* The symptoms are masked at first by spinal shock.

1. *Extra medullary.* Produces mild symptoms as a rule. (Rare cases of ascending paralysis as the spinal theca fills with blood.)
2. *Intramedullary* (Hæmatomyelia). Shows features of dissociated anæsthesia, with some lower motor neurone paralysis over the affected segments.

(e) *Inflammation and later fibrosis, or pressure of an abscess.*

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2. Spinal shock or concussion. This may follow bullet wounds in the region of the cord. The paraplegia last three days to three weeks and goes on to complete recovery. The symptoms of the above types of injury tend to be less complete than the succeeding two types.

3. Compression. This may be due to a variety of causes.

(a) *Œdema.* Possibly the most frequent cause in cases which recover completely.

(b) *Pressure of a foreign body.*

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(e) *Inflammation and later fibrosis, or pressure of an abscess.*

(*f*) *Prolapse of a nucleus pulposis.* This may be either lateral, with features of nerve root irritation, *e.g.*, sciatica, brachial neuritis, or central, with features of cord compression in the cervical region, or bilateral nerve root involvement in the lumbar region.

4. PARTIAL AND COMPLETE TRANSECTION OF THE CORD. There is hæmorrhage around the ends of the cord, which later become rounded off and attached to the dura. Small cystic cavities may develop containing degenerated blood.

Neurological features of cord injuries. It is only proposed here to give a brief outline of the main features of cord lesions.



FIG. 233. Patient with fracture of the lumbar spine and cord symptoms treated on a double Braun's splint, with skeletal traction through both tibial tuberosities.

INCOMPLETE TRANSECTION OF THE CORD. 1. Stage of spinal shock. There is a flaccid paralysis, with loss of all reflex activity, except perhaps a flexor plantar response, and loss of all sensation. This stage is not so complete as in total section of the cord, and tends to pass off earlier, usually four to five days, sensibility recovering first.

2. Stage of returning reflex activity. (*a*) Tone returns to smooth muscle first, with improved bladder function and improved vasomotor condition of the skin.

(*b*) Tone returns to voluntary muscle, but the extensor muscles have the maximum tone, producing " paralysis in extension." This is due to the dominance of the extra-pyramidal tracts, especially the vestibulo-spinal.

(*c*) Involuntary movements are infrequent.

(*d*) Reflex movements. Extensor thrust reflex may be elicited,

or the crossed extensor reflex. The deep reflexes become easier to elicit, and the knee jerk shows a prolonged relaxation from increased extensor tone.

COMPLETE TRANSECTION OF THE CORD. 1. Stage of spinal shock. Severe and lasts two to three weeks. The persistence of this stage over one week indicates that recovery is unlikely.

2. Stage of reflex activity. (*a*) Tone returns first, as above, to smooth muscle.

(*b*) Tone returns to voluntary muscle, but the flexor muscles have the maximum tone, producing "paralysis in flexion." All muscles are much more hypotonic than in incomplete lesions.

(*c*) Involuntary movements and reflex activities are frequent.

(*d*) Reflex movements. The flexor reflex, which is a fractionated withdrawal reflex from nociceptive stimuli, returns, and with it various amounts of withdrawal. The mass reflex may be elicited by stimuli, and the coitus reflex. The deep reflexes return some weeks after the flexor reflexes.

3. Stage of failure of reflex activity. The threshold of stimuli required to produce reflex action is raised, retention sets in again, vasomotor control is lost, bed sores develop, and muscles waste grossly.

The development of a true Brown-Sequard syndrome is a very rare occurrence with fractures, though it may occur atypically.

Paralysis at various levels. These may be briefly summarised as follows :

Above C3. Respiratory paralysis, complete flaccidity, and early death if artificial respiration is not maintained.

C5 to C6. Quadriplegia but some retention of shoulder girdle function.
Intercostal paralysis.
Absent tendon and skin reflexes.
Anæsthesia below the clavicle.
Bladder and bowel retention and priapism.

T1 to T12. Paraplegia.
Absent deep reflexes in the lower limbs.
Absent cremasteric and plantar reflexes. The upper abdominals may remain in lower thoracic injuries.
Bladder and bowel retention and priapism.

L1 to L5. Partial flaccid paraplegia, depending on the roots of the cauda equina involved.
Above L4. Knee, ankle, and plantar responses absent.
Below L4. Knee jerks present.
Perineal anæsthesia. Patchy anæsthesia of the extremities.
Temporary bladder and bowel retention.

It will thus be seen that all injuries to the nervous system are made up of combinations of

Cord damage, above the second lumbar vertebra.
Root damage, to the issuing spinal nerves ; to the cauda equina

The care of cases with paralysis. Difficulties arise from : (1) The maintenance of correction of the deformity. (2) Retention of urine, and urinary infection. (3) The presence of constipation or incontinence. (4) The development of bed sores. (5) The development of deformities from muscle imbalance.

The deformity is as easily corrected as in cases without paralysis, but the method of retention is difficult as any fixation is likely to produce bed sores. For this reason patients have been nursed on water beds, in plaster beds, and even in warmed oil. Plaster beds are very likely to produce pressure sores even if the pressure on the sacrum is relieved by having both legs supported on Braun's splints with traction on pins through the tibial tubercles (Fig. 233).

If open operation has been required nursing is rendered much simpler if the fracture has been fixed by plates and bolts on either side of the spinous processes. This avoids the need for any external support of the spine and a nursing regime with regular turning at two-hourly intervals can be instituted. Good team work is essential if skin necrosis is to be avoided.

The correct choice of treatment for cases with paraplegia is extremely difficult and is still the subject of considerable debate. Attention must be concentrated on the care of the skin, and it may be advisable to forget the fracture if it is relatively stable. If it is unstable or there are added reasons for exploration, such as a progressive lesion or severe root pain, spinal fixation as in open injuries is considered by many to give the best basis for the subsequent careful nursing regimen. Above all experience is essential, and special centres will achieve results unobtainable in an isolated unit.

Bladder function and control. Following damage of the cord or cauda equina the bladder becomes atonic and painless retention of urine supervenes during the course of twenty-four to forty-eight hours. If unrelieved dribbling incontinence takes place, the bladder remaining partly distended. After a further period, if the patient survives, partial recovery of bladder-wall tonus occurs leading to more active incontinence and a reduction of bladder capacity. When the nervous injury has involved the cauda equina or conus-medullaris, the reflex arc subserving micturition is abolished and an autonomous bladder results with permanent residual urine and persistent overflow. If the lesion is above the reflex centre for micturition in the second sacral segment all voluntary control

remains abolished but an automatic bladder may develop characterised once again by incomplete emptying during intermittent bouts of incontinence. In either event a quantity of residual urine is permanently present, and the urinary tract is exposed to the risk of infection and stone formation which may determine the eventual issue.

During the early stages of atonic distension when there is doubt as to whether permanent nervous damage has been sustained, it may be legitimate to relieve the retention by the intermittent passage of a catheter using full aseptic precautions. If, however, voluntary voiding is not established after two or three attempts, or if further neurological examination indicates an irrecoverable lesion, high suprapubic cystotomy drainage should be instituted. With subsequent recovery of bladder tonus and the establishment of autonomous or automatic micturition it may be possible to close the suprapubic fistula and train the patient to improve his voiding (and thus to reduce the frequency of incontinence) by initiating new reflex mechanisms or contracting his abdominal muscles. Further assistance may also be afforded by judicious perurethral resection of the bladder neck to allow more complete emptying. Throughout the course of micturitional disturbance the urine should be rendered acid and urinary antiseptics given as required to minimise the risk of infection and stone formation. When also the condition of the patient permits, periodic changes of position will assist, in association with a copious fluid intake, to reduce the liability to recumbency calculi.

Incontinence is more trouble than constipation as it tends to produce bed sores. Constipation is treated by a daily enema, and this is not always simple as the patient tends to retain it.

Bed sores are avoided by relieving the known pressure points, careful nursing on a sponge rubber mattress and frequent turning of the patient. The skin is carefully hardened with spirit, and powdered. Hot-water bottles are taboo. When developed the necrotic tissue may be removed by foments of 10 per cent. aluminium acetate. The sore is then protected by elastoplast, which is only changed when dirty. If pressure is kept from the skin it usually heals under such treatment. When the patient is better, ultraviolet light, fresh air and sun, may be used to stimulate healing.

Deformities can only be prevented by adequate splinting. A patient nursed on Braun's splints with the feet held in the neutral position is having his flexion contractures of the hips and knees controlled, and the equinus deformity of the feet can be easily corrected. Should deformities develop in spite of this tenotomies are usually necessary for their correction, or neurectomies of the stronger muscle groups.

Lesions of the cauda equina. As the spinal cord ends at the level of the second L. vertebra, injuries to the spine below this involve the cauda equina. Such lesions take the form of a peripheral nerve injury, with a root distribution. Thus there will be flaccid paralysis, with complete loss of reflexes, patchy loss of sensation, and sensory paralysis with incontinence of the rectum and bladder. Slow recovery of function is observed, as in peripheral nerve lesions elsewhere, but the patient is liable to the complications of a long-standing partial lesion of the cord, and must be nursed as such. In a few cases where there is evidence of pressure of bone laminectomy and nerve suture has been carried out.

Compound injuries of the spine. The treatment of these lesions may be worked out from a consideration of the treatment of compound fractures in general, and of those of the head in particular. All damaged tissue is removed. The theca is preserved intact if possible. If it is impossible to close the wound owing to loss of tissue, it is packed with gauze as in other cases of gross tissue loss, and the patient nursed in a plaster bed. Occasionally it is possible to treat clean rifle bullet wounds expectantly, but generally speaking the track should be opened up, cleaned and the edges excised. Drainage must be inserted if the hæmostasis is doubtful.

Operative treatment of cases with paralysis. The symptoms of compression are the same as those of complete or partial transection of the cord. First the stage of spinal shock must be allowed to pass off, unless the fracture is compound or there is definite evidence of bone or a foreign body pressing on the cord which are the only indications for immediate laminectomy. Operation should not be carried out in the stage of primary shock or in the presence of infection. Operation is rarely indicated and can serve only one purpose, the relief of pressure on the cord. In the absence of X-ray evidence of this the distinction between a lesion of the cord due to partial or complete section and one due to pressure is very difficult. A test of paramount importance to determine the presence of pressure on the cord is the Queckenstedt test. This consists of performing lumbar puncture below the level of the lesion, and measuring the pressure with a manometer. The jugular veins are now pressed upon, thus causing a rise in intracranial pressure. If there is no block in the spinal canal this will be fairly rapidly transmitted to the manometer. If there is a block, no change in pressure will occur, and the fluid withdrawn may be tinged yellow, and may show a great rise in protein content (Froin's syndrome). If the block is partial the rise in pressure will be gradual, and it will subside slowly. By this means a suspicion of pressure on the cord can be confirmed, and it is only in the presence of a positive Queckenstedt that operation is to be recommended. Factors in the clinical progress of the case which may suggest pressure are the development of paralysis after a stage of improvement in an incomplete case. Operation is useless in complete cases and in incomplete cases which continue to improve.

We may sum up the indications for laminectomy as follows:

1. Immediate. Compound wounds, foreign bodies and bone pressing on cord. Dislocations.

2. In incomplete cases only if improvement suddenly ceases.
3. If paralysis occurs later in the case.
4. For the relief of severe root pain.
5. For suture of the nerve roots in cauda equina lesions.

PROGNOSIS. In all cases of complete lesion it is very bad, as, if the patient does not die of the immediate lesion, he may die later from renal infection or pressure sores. In incomplete lesions which do not make a good recovery it is a little better, but it usually means that the onset of complications is only delayed, perhaps for years. In all cases it must be borne in mind that a final prognosis can only be given after watching the patient for a month or longer to allow the effects of spinal shock to wear off completely.

FURTHER READING

General

DAVIS, A. G. "Tensile Strength of the Anterior Longitudinal Ligament in the Relation to Treatment of 132 Crush Fractures of the Spine," *J. Bone and Joint Surg.*, 1938, 28, 429.

WATSON JONES. "The Results of Postural Reduction of Fractures of the Spine, *J. Bone and Joint Surg.*, 1938, 20, 567.

ROGERS, W. A. "Cord Injury during Reduction of Thoracic and Lumbar Vertebral Body Fracture and Dislocation," *J. Bone and Joint Surg.*, 1938, 20, 691.

JEFFERSON, G. "Discussion on Spinal Injuries," *Proc. Roy. Soc. Med.*, 1927–28, 21, 625.

BIRKETT, A. N. "Injuries and Derangements of the Spinal Column," 1950, Chap. 11; "Modern Trends in Orthopædics." Butterworth, London.

NICOLL, E. A. "Fractures of the Dorso-lumbar Spine," *J. Bone and Joint Surg.*, 1949, 31B, 376.

Cervical Spine

CRUTCHFIELD. "The Treatment of Injuries of the Cervical Spine," *J. Bone and Joint Surg.*, 1938, 20, 705.

MCKELLAR HALL. "Clay Shoveller's Fracture," J. Bone and Joint Surg., 1940, 22, 63.

ROBERTS, S. M. "Fracture and Dislocation of the Cervical Spine," *J. Bone and Joint Surg.*, 1937, 19, 199.

BARTON, L. G. "The Reduction of Fracture Dislocations of the Cervical Spine by Skeletal Traction," *Surg. Gynæ. and Obsts.*, 1938, 67, 94.

BARNES, R. "Paraplegia in Cervical Spine Injuries," *Bone and Joint Surg.*, 1948, 30B, 234–244.

COHEN, K. "Atlanto-axial Fracture Dislocation," *J. Bone and Joint Surg.*, 1949, 31B, 395.

TAYLOR, A. R. "The Mechanism of Injury to the Spinal Cord in the Neck without Damage to the Vertebral Column," *J. Bone and Joint Surg.*, 1951, 33B, 543.

GROGONO, B. J. S. "Injuries of the Atlas and Axis," *J. Bone and Joint Surg.*, 1954, 36B, 397.

Kümmell's Disease

KUMMELL. "Die Posttraumatischer, Wirbelerkrankung," *Arch. f. Klin. Chir.*, 1921, 118, 876. (Review of disease, with full references.)

HOSFORD, J. P. "Kummell's Disease," *Lancet*, 1936, 230, 249. (Short summary of modern views and further references.)

Neurological Aspects

RIDDOCH. "Injuries to the Spinal Cord," *Proc. Roy. Soc. Med.*, 1927–28, **21**, 625.

NAFFZIGGER, H. C. "The Neurological Aspects of Injuries to the Spine," *J. Bone and Joint Surg.*, 1938, **20**, 444.

DENNY BROWN and GRAEME ROBERTSON. "The State of the Bladder and its Sphincters in Complete Transverse Lesions of the Spinal Cord and Cauda Equina," *Brain*, 1933, **56**, 149 and 397.

WATKINS, K. "Bladder Function in Spinal Injury," *Brit. J. Surg.*, 1935–36, **23**, 734.

BARRINGTON, J. F., *et al.* "The Treatment of the Paralysed Bladder." Discussion, *Proc. Roy. Soc. Med.*, 1943, **36**, 197.

GUTTMA[illegible] "Traumatic Paraplegia," *J.* [illegible]

HARDY [illegible] Traumatic Paraplegia," *J. Bone and Joint Surg.*, 1954, **36B**, 368.

CHAPTER XVIII

FRACTURES OF THE RIBS AND STERNUM

Surgical anatomy

The thoracic cage, which serves as a protection to vital organs and at the same time as support for the bellows action of the respiratory muscles, is extremely elastic, particularly in the earlier years of life, and so resistant to injury. Later on, as the costal cartilages calcify, the ribs also become more brittle, and the frequency of fracture increases. The upper ribs, which do not move much with the respiratory excursion, are protected by the shoulder girdle. The lower ribs have a protection from their increased mobility, particularly the last two, aptly named "floating ribs." Injuries occur most frequently to the fifth to ninth ribs, which have the greater respiratory excursion and so are more difficult to keep at rest.

Fractures of the Ribs

Mechanism of fracture of the ribs. DIRECT VIOLENCE. This is the most common cause, fracture occurring at the point of impact of the blow, and the number of ribs fractured depending directly on the area of chest struck and the force of the blow. The fragments tend to be driven inwards, and so injuries to the pleura and the lung are more common than in fractures from indirect violence.

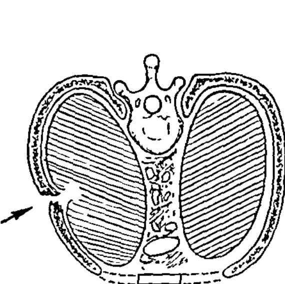


FIG. 234. Fracture of the ribs due to direct violence. The fractured surfaces may be driven into the lung.

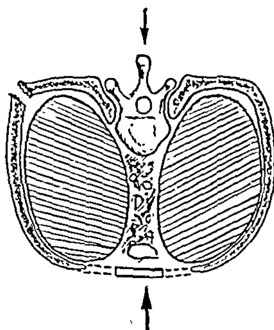


FIG. 235. Fracture of the ribs due to indirect violence. The ribs yield at the angle and the lung is unlikely to be lacerated.

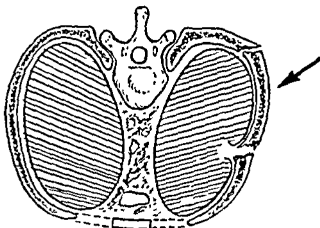


FIG. 236 When the ribs are fractured by direct violence, if the force continues, a fracture by indirect violence at the angle of the ribs may follow (see Fig. 242). Note that the unsupported chest wall between the fractures may show paradoxical movements.

INDIRECT VIOLENCE. This usually takes the form of crushing injuries, such as occur in a stampeded crowd of people trying to get out by a narrow exit. The elasticity of the rib is overcome, and it fractures at a point near the angle as a rule, though in a few cases it may break just lateral to the tubercle. The fragments tend to bow outwards, so the pleura usually escapes damage. When one rib is



FIG. 237. Compressing the thorax antero-posteriorly to test for fracture of the ribs (springing the thorax)

fractured in two places the fracture near the angle is due to indirect violence, transmitted from the region of the direct violence which has caused the other fracture.

MUSCULAR VIOLENCE from sneezing or coughing is a rare cause.

The fractures may be oblique or transverse, or comminuted. Displacement is as a rule slight. Compound fractures, except those from gunshot wounds, are rare

Symptoms. After a typical injury, such as falling and striking

the side on the kerb, the patient complains of pain, which is usually well localised, over one or more ribs. The pain is increased by movement, coughing, straining, and similar actions, and the patient may press his hands on the chest to prevent movement. Bruising, local crepitus, and deformity may be found. In thin people running the fingers along the ribs will give exact information. In the obese an X-ray may be necessary to be certain a fracture is present. Auscultation may enable slight crepitus to be heard. Compression of the thorax from spine to sternum (springing the ribs) will produce pain, localised to the site of fracture. To these features may be added the features of complications, due to injury to other structures in the chest or abdomen.

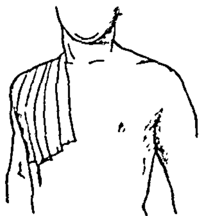


FIG. 238. Strapping the chest completely The vertical layers, applied in inspiration.

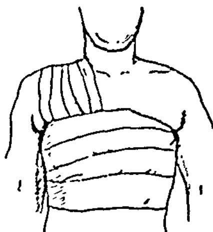


FIG. 239. The horizontal layers, applied in expiration of extensible strapping.

DIAGNOSIS. This is usually simple. Certain cases of spontaneous fracture from cough have been diagnosed as pleurisy or intercostal myositis. An X-ray is usually conclusive, but in fractures in the mid-axillary line it is necessary to have an oblique or lateral view, as they may not show in an A.P. film.

Treatment. This is often difficult to carry out satisfactorily though it is comparatively simple. In fractures of the upper ribs the parts can be little further immobilised. Rest in bed is all that can be done to supplement the natural rest of muscular spasm. Below the level of the fourth rib strapping can be used. To control the ribs satisfactorily it must be remembered that the ribs have a hinged upward movement on the vertebral column, which at the same time increases the diameter of the chest. Maximum rest can only be obtained by preventing downward movement of the ribs, which is very difficult, by strapping passed over the shoulder from the twelfth rib behind to the costal margin in front, applied in *inspiration*. Over this is applied a circular plaster which completely

surrounds the chest, and is applied in overlapping layers from below upwards in *expiration*. Fixation as firm as this can only be tolerated by healthy patients in whom it will give much relief. In patients with cardiac or respiratory difficulty it cannot and should not be applied. A compromise which aims at as much fixation as the patient can bear must be arrived at. Sometimes a single 4-inch wide piece of strapping passed completely around the chest at the site of fracture may be suitable, in others only one half of the chest can be strapped as previously described. The use of single-stretch strapping makes the patient much more comfortable than ordinary strapping. In fat women the breast makes strapping awkward, and a tight binder may have to be substituted.

The most troublesome feature of fractured ribs is often the pain and the inability to cough. In old people this may be extremely serious, limiting the respiratory excursion and interfering with rest. It is best treated by the infiltration of the fracture hæmatoma with novocaine, which is a very comforting procedure, and well worth keeping in mind in any case in which pain is to the fore.

In more complicated injuries, where several ribs are crushed, the patient is more comfortable in the sitting or half-sitting position in bed. Strapping is contra-indicated particularly if there is any depression of the ribs. Compound fractures are treated as compound fractures elsewhere. It is particularly important to control a "sucking" wound by excision and suture as it interferes with the air entry into the lung. Similarly, in "stove in" chests, the free portions of the chest wall undergo paradoxical movements with respiration, and this reduces the air entry. It is important that this free mass of ribs and muscle should be fixed without constricting the chest. This can be done by applying elastoplast over the side of the thorax and then covering this with a layer of plaster. When the plaster sets the mobile portion remains attached by the elastoplast to the plaster. Foreign bodies should not be removed immediately from the lung or deeper structures in the absence of complications, but only if superficial in the chest wall.

PROGNOSIS. Rapid and satisfactory union occurs even in the untreated case in three to five weeks. In a small percentage of cases, particularly in the old, there is a troublesome persistence of pain at the fracture site. Its origin is difficult to determine, and it can only be combated by novocaine injections and physiotherapy. After some months it subsides.

In more severe chest injuries the prognosis is that of the complications present (*q.v.*).

INJURIES TO THE COSTAL CARTILAGES. These may consist of fracture, separation at the costo-chondral junction, or at the chondro-

sternal junction. The history and symptoms are similar to that of fractured ribs, but the injury is localised over a cartilage. The X-ray will not show the lesion except in cases in which the cartilage is calcified. Where there is an obvious costo chondral dislocation it may be reduced by arching the patient's back over a pillow or the knee and getting him to take a deep inspiration. Strapping is seldom required for these lesions.

Rarely union between the rib cartilages at the lower costal margin does not occur or they are separated by trauma, and a condition of slipping cartilage develops, in which during muscular movements the lower cartilage slips over the upper one, producing an unpleasant sensation and persistent local tenderness. Excision of the cartilage under local anaesthesia is a satisfactory cure.

Fractures of the Sternum

These are due either to direct violence or to hyperflexion of the spine. The fracture is usually transverse, and there is little displacement. The sites most commonly involved are the centre of the bone, or the synchondrosis between the manubrium and body. Rarely the xiphisternum is fractured from the body. Displacement if present is due to flexion injury and should raise suspicion of a fracture of the spine. The lower fragment is usually displaced forwards (Fig. 241).

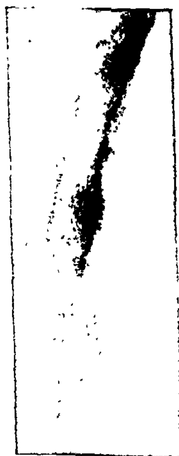


FIG. 240. Lateral view of a fracture of the sternum, due to direct violence.



FIG. 241. Fracture of the sternum accompanying crush fracture of the second thoracic vertebra.

DIAGNOSIS. This is usually straightforward, and is confirmed by a lateral X-ray. A.P. X-rays will not show the lesion. Where there is displacement the patient tends to walk in a stooping position.

TREATMENT. In cases without displacement rest in bed till the acute pain has gone, followed by strapping, is all that is required. Where there is displacement it can be reduced by hyper-extension of the thoracic spine. Local anæsthesia may be used to relieve the pain while this is being done.

Complications of thoracic injury. 1. HÆMOPTYSIS. This indicates damage to the lung, and the degree of hæmoptysis indicates to some extent the site and size of the lung injury. Thus a small amount of pink frothy sputum coughed up some hours after the injury indicates a small degree of peripheral lung damage, while a continued hæmoptysis of dark blood occurring rapidly after the injury indicates rupture of a large vessel near the root of the lung It is to be remembered however that a serious injury to the lung may be present without hæmoptysis owing to the cessation of hæmorrhage with the collapse of the lung and the inhibition of the cough reflex by the patient on account of pain.

2 SURGICAL EMPHYSEMA. Indicates perforation of the lung. It settles down rapidly even if moderately extensive. Rarely a bronchus may be ruptured with mediastinal emphysema, which first shows itself at the neck. It is of serious import, and can only be given supporting and expectant treatment.

3. HÆMOTHORAX. This is only of importance when of some amount, indicating that an artery, either in the lung, or the internal mammary, or an intercostal vessel, is ruptured. Blood in the pleural cavity does not clot, and can be easily aspirated. After the hæmorrhage has stopped this should be done if there is any amount present in the chest in order to hurry resolution. Difficulty arises in the cases in which the hæmorrhage continues, or there are symptoms of lung compression These should first be relieved by aspiration, and this followed by blood transfusion if the patient is exsanguinated. Should the hæmorrhage still continue operation must be carried out. Aspiration must be tried first to be certain that the hæmorrhage has not ceased as open operation is a risk not lightly to be undertaken.

4. PNEUMOTHORAX May be due to a penetrating wound of the pleura or to a wound of the lung. In the open variety, the free communication of the pleural cavity with the air allows the lung to collapse, and air is sucked in and out the wound, often frothing up the escaping blood in the wound. Such a wound needs to be closed at once with a wet dressing preparatory to its excision. and suture to assure air entry into the lungs.

The closed variety of pneumothorax is unimportant provided the

wound is not of a valvular type, which allows the entry of air but prevents its expiration (tension pneumothorax). Such a condition is most commonly due to a wound of the lung, and results in a steady rise in intra-plural pressure with marked mediastinal displacement, and much increased respiratory difficulty. The discovery of such a condition demands immediate relief by needling the pleural cavity and allowing the air under pressure to escape. The needle may be left in some time if necessary to continue the decompression.

5. Traumatic cyanosis (asphyxia). This produces a dramatic coloration of the skin of the face and shoulders above the level of the second rib, together with extensive subconjunctival hæmorrhages. It is due to : (1) A wave of back pressure in the veins of the chest, head and upper extremities, which are devoid of veins. This occurs instantaneously following a blow which may be of short duration, and is responsible for the petechial hæmorrhages in the skin and the subconjunctival hæmorrhages. (2) These hæmorrhages may occur on top of a cyanosed condition of the skin, or alone. Where cyanosis is present it is due to a paralysis of the skin venules, due to long-continued venous back pressure, and demands that the thorax be compressed for some minutes. Slow compression of the thorax may produce this condition without petechiæ. The normal tone is restored to the skin capillaries and venules in three to five days, the "blue" discoloration fading without intermediate pigmentary change. This leaves the petechiæ more distinct, when present, and these fade with the usual colour changes of a hæmatoma in ten to twelve days.

Treatment. The cyanosis being entirely peripheral no treatment to the chest is of avail in clearing it up. Oxygen may, however, be required for the damage to the lung associated with such a lesion, which may be a contusion or mild pulmonary œdema.

A most important feature of the condition is the occurrence of retinal hæmorrhages and optic atrophy, which not infrequently follow.

6. Contusion of the heart. Bruising of this and other mediastinal structures is first shown by severe shock and precordial pain. More severe injury may rupture the heart or great vessels.

7. Massive collapse of the lung. This may follow other injuries, and the pathology is not clear. The lung is collapsed but there is a negative pressure in the thorax and the mediastinum is deviated to the side of the lesion. It can best be diagnosed in the [illegible]

[illegible]

[illegible] lung. The condition settles down of its own accord in one to three weeks.

VISCERAL INJURIES ASSOCIATED WITH FRACTURES OF THE LOWER RIBS. On account of their resilience the ribs are seldom fractured save by severe direct trauma. With such force, however, the solid viscera in the upper abdomen are particularly susceptible to injury



FIG. 242. Fracture of the ribs A healing fracture of the four upper ribs, with early callus has been followed by a recent fracture of three of the same ribs more anteriorly

and may become ruptured or avulsed from their attachments. The immediate danger in this event lies in the occurrence of internal hæmorrhage, either intra-peritoneal (as in rupture of the liver or spleen) or into the soft tissues at the back of the abdomen (as in rupture of the kidney). In many instances the effect of the accompanying fracture is slight and there is little difficulty in distinguishing the signs of internal bleeding in the ordinary manner.

In some cases, however, in severely shocked patients (perhaps

with multiple injuries) evidence of hæmorrhage is harder to assess and careful examination of the abdomen at frequent intervals during a probationary period of transfusion is required. Gravitation of blood within the peritoneal cavity may produce confusing signs with regard to the location of the injured viscus, and it is well to reconsider the site of the initial trauma when planning surgical exploration. Retroperitoneal bleeding may likewise give rise to ileus and abdominal distension which further obscure the issue. Where signs of intra-peritoneal bleeding become manifest transfusion and early laparotomy are called for, and suitable measures taken to control hæmorrhage either by ligation or packing.

Somewhat greater conservatism may be indicated in cases of suspected rupture of the kidney, provided that associated intra-peritoneal injury can be reasonably excluded. Immediate exploration may be warranted, however, if a large swelling appears rapidly in the loin, or if a sustained fall in blood pressure and increasing pulse rate indicates serious continuous hæmorrhage. Conservative treatment by suture to arrest bleeding from the kidney may be practicable in some instances, and steps should be taken to ensure the existence of a contra-lateral kidney before any more radical procedure is undertaken. Profuse hæmaturia alone is seldom an indication for early interference and can generally be combated by transfusion. If exploration can, therefore, be deferred an opportunity will generally occur for proof to be obtained of the presence of a functional kidney on the opposite side by intravenous pyelography. In severely shocked patients a period of anuria may ensue on account of generalized hypotension causing a fall in glomerular filtration pressure. In other cases with severe internal hæmorrhage or associated crush injuries renal excretion may be impaired by cortical necrosis induced by the renal " shunt " mechanism. After preliminary measures to restore blood pressure any continuing anuria requires careful biochemical supervision and conservative treatment by the Bull regime (with avoidance of over-hydration by ill-considered infusion) in association with expert medical advice.

FURTHER READING

General

SAUERBRUCH and O'SHAUGHNESSY. "Thoracic Surgery," London, 1938.

TUDOR EDWARDS, A. "Treatment of Injuries of the Chest," *Brit. M. J.*, *1938, 2, 1096.*

Associated Injuries

HAMILTON BAILEY. "Injuries to Kidney and Ureter," *Brit. J. Surg.*, 1923, 11, 609.

BUTLER, E. "Injuries of the Chest and Abdomen," *Surg. Gynæ. and Obsts.*, 1938, 66, 448.
BIZARD, J. D. "Slipping Ribs. Report of a Case," *J.A.M.A.*, 1931, 97, 23.
BONNIN, J. G. "Traumatic Asphyxia," *Lancet*, 1941, *ii.*, 333.

Sternum

STICK, W. G. "Fractures of the Sternum," *Am. J. Surg.*, 1933, 22, 266; 1937, 38, 560.

CHAPTER XIX

THE CLAVICLE

Anatomy. Development. First bone to appear. Laid down in membrane bone, ossification commencing in the centre of this at two centres in the sixth week. The two ends are laid down later in cartilage (probably indicating the fusion of two morphologically distinct bones) but ossification spreads to them from the primary centre. One secondary centre for the disc of bone on the sternal articular surface appears at 20 and unites at 25 years of age. It is completely intracapsular.

The bone is S-shaped, with two broader and stronger ends, and a weakness at the junction of the outer third and middle third, due to :

1. Groove for the subclavius.
2. Alteration in the internal architecture of the bone.
3. Junction of two curves.
4. Foramen for the nutrient artery.

An elastic rod broken by compression tends to break near its centre, and in

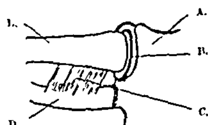


FIG. 243 The sternal end of the clavicle A. Manubrium sterni. B. Intra-articular fibro-cartilage. C. Rhomboid ligament. D. First rib. E. Sternal end of the clavicle.

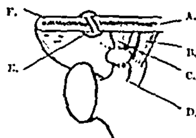


FIG. 244. The acromial end of the clavicle. A. Section of the clavicle. B. Conoid ligament. C. Trapezoid ligament. D. Coracoid process. E. Sloping surfaces of the acromio-clavicular joint. F. Section of the acromion.

the case of the clavicle, the weak points above determine the site. The double curve of the clavicle is important as it increases the elasticity of the bone, which is the only bony bridge connecting the superior extremity with the trunk.

Attachments. Ligaments are more important than muscles, which are the deltoid, sternomastoid, subclavius, pectoralis major, and trapezius.

Ligaments. Sternal end.

Intra-articular fibrocartilage, bound to the upper surface of the clavicle, and lower aspect of the sternal joint.

Capsule, reinforced by fibres of the sterno-mastoid.

Interclavicular ligament.

Rhomboid ligament. Very strong, attaching the clavicle to the first rib.

Ligaments. Acromial end.

Coracoid ligament. }
Trapezoid ligament. } Attaching clavicle to the coracoid process.

These form the main strength of the coraco-acromial joint pulling

down the oblique articulating surface of the clavicle which would otherwise tend to ride up.

Joint capsule, reinforced a little above.

Relations. Arches over the important structures passing from the thorax and neck to the axilla, which in spite of their position between two bones are seldom injured.

Injuries to the Clavicle

1. Fracture at the junction of the outer and middle third.



FIG 245. The fracture sites in the clavicle. (The numbers correspond to those in the text.)

2. Fracture of the acromial tip lateral to the trapezoid ligament.
3. Fracture of the acromial end in the region of the conoid and trapezoid ligaments. (Rare.)
4. Fracture of the sternal end. (Uncommon.)
5. *Separation of the epiphysis.* (Very rare.)

Type of injury. DIRECT VIOLENCE. From bars falling on the shoulder and the like. Produces any of the above fractures, and

FIG 246. Fracture at the junction of the outer and middle third of the clavicle showing well the usual downward and medial displacement of the outer fragment and the shoulder.

is the only type of injury which may produce comminution and damage to vessels and nerves.

INDIRECT VIOLENCE. Force is transmitted through the extended arm or from the elbow, or perhaps more frequently from a fall on the shoulder. Fracture occurs at the weakest point, the type varying with the age of the patient.

Greenstick, in children up to the age of ten.
Compression, or infraction fracture. In children. Rare.
Complete, in adults, at classical site.

Fracture is most common in children. In spite of the subcutaneous nature of the bone the fracture is nearly always simple. Damage to nearby structures is rare. The brachial plexus is seldom injured. Paralysis, if it occurs, is always temporary, and little good is to be done by interference, so such injuries are left alone. The subclavian artery is rarely injured, the subclavian vein more frequently.

Fracture of the shaft. 1. COMPRESSION. Occurs in the young under six years. There is complaint of local pain, and a swelling may be palpable. X-ray shows the bone intact, but a slight swelling near the weak point, and an alteration in trabecular lines. The child can use the arm, but is reluctant to do so.

Treatment. (See below.) Sling.
Two-singlet method.

2. GREENSTICK. Features similar to compression fractures, from which it is distinguished by the presence of angulation, and a little more pain and disability. Local bruising is often absent. Local pain, and reluctance to use the arm, and local tenderness are found. If in doubt the X-ray confirms the diagnosis.

Treatment. Figure-of-eight bandage and sling, or sling alone.

3. COMPLETE. Break tends to be oblique or spiral, with finely jagged ends if due to indirect violence, the line of the fracture running forwards and medially. In direct violence it tends to be more transverse.

Displacement. Outer fragment. The weight of the shoulder pulls it down. Pectoral muscles pull shoulder medially and forwards.

Inner fragment. Fixed by the pull of the rhomboid ligament. and the sternomastoid, which may tilt it a little upwards.

As a result of this the medial fragment overrides the lateral, which lies a little below and medially displaced (Fig. 246).

Symptoms and signs. Arm on the affected side is rendered powerless.

Patient supports the elbow with the opposite hand (as he will for other fractures of the arm and shoulder).

Head is inclined to the affected side to relax the sternomastoid, and the trapezius.

Local pain, tenderness, bruising and deformity.

Crepitus is usually felt.

Shoulder may be higher or lower than on the uninjured side, depending on the amount of muscle spasm in the trapezius.

Fracture of both clavicles. Rare. Due to crushing injuries. Both arms are powerless, and their weight on the thoracic cage may, together with the loss of the accessory muscles of respiration, cause acute respiratory embarrassment in elderly people.

This can be treated with bilateral abduction on pillows or Cramer wire splints (Fig. 139). This frees the thorax and the patient can be sat up. Two-arm Thomas splints have been used if the patient must be nursed recumbent.



FIG. 247. Figure-of-eight method of drawing the shoulders back, using two triangular bandages, knotted behind. The cross bandage in front is necessary to prevent slipping over the shoulders.

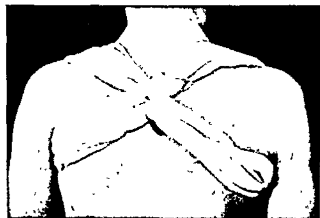


FIG. 248. Back view of the figure-eight bandages

Treatment of complete fractures of the clavicle. The multiplicity of methods invented indicates that none are universally used, or completely satisfactory. The results are good as far as function is concerned, whichever method is employed, but there may be a marked overlap, and a mass of subcutaneous callus, which is unsightly. Non-union is almost unknown (Fig. 74), and when fibrous union occurs, the functional result is quite satisfactory.

All methods of treatment depend on increasing the distance between the two ends of the clavicle, by :

1. Drawing the shoulder backwards.
2. Drawing the shoulder outwards.
3. Elevating the shoulder.

or combination of these methods.

The most suitable treatment depends largely on the age.

BETWEEN ONE TO FOUR YEARS. A child does not require more than a sling, but wriggles out of this. A suitable method of retention, if the mother is helpful, is to get her to put two singlets on the child, one under the arm and the other over it, and sew the two together around the arm and hand, while the hand rests on the opposite shoulder. This has the advantage of remaining in place however much the child wriggles, which very few other methods have at this age.

BETWEEN FOUR TO TEN YEARS. The figure-eight application of the three handkerchief method will be found most satisfactory. Two triangular bandages are folded over some lint to make some extra padding till they form two bandages about 2 inches or more wide. These are put around each axilla, and then tied crosswise at the back, thus pulling the shoulders back. In small children this is all that is necessary, but in larger children and in adults it is necessary to pull the two axillary rings nearer to the mid-line, by a bandage pinned across the front. This prevents the rings slipping over the acromial process, but draws the point of pressure nearer to the fracture site.

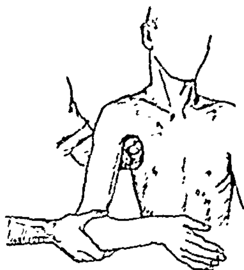


FIG. 249. Reduction of a fractured clavicle over the fist in the axilla.

ADULT METHODS. *Reduction.* This may be made after the injection of a local anæsthetic, or without it in many cases, by putting the fist in the axilla and levering the arm to the side over it. It can also be made by placing a knee against the back and pulling both shoulders back over it. Slow reduction may be obtained by retentive apparatus, which is daily tightened. This is probably the best method, as, after reduction, most fractured clavicles tend to slip back to their original position.

Retention. 1. Bed, with a pillow between the shoulders. Unnecessarily tedious. Where the minimum of callus and deformity is required this can be obtained by an abduction splint.

2. Abduction splint. Applied as for fractures in the region of the neck of the humerus, with extension on the upper arm. All displacements can be corrected by this method, but it requires constant supervision and is clumsy.

3. Sayre's method. Pad in axilla. Strapping is passed around

the arm, with the adhesive side out, and fastened to the back, so drawing the whole arm backwards. An oblique strip split over the olecranon is now passed from behind forwards, over the elbow, and up along the forearm to the opposite shoulder. By this means the elbow is carried forward and the shoulder levered up and back. It is a useful temporary measure, but it tends to slip, is uncomfortable, and makes the skin sore after a time (Figs. 250, 251).

4. Wharton Hood's method. Direct pressure on the fracture with strapping passed from below the scapular of the opposite side

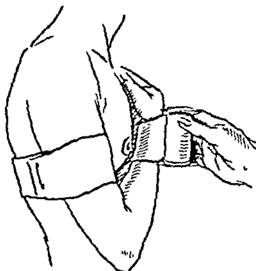


Fig. 250 Sayre's method. The first layer. The strapping applied sticky side out to the arm, may be brought completely around the chest and over this again.



Fig. 251. Sayre's method. Second layer. A pad placed between the hand and the chest makes the patient more comfortable. Note also the pad over the olecranon.

over the shoulder, to below the nipple of the opposite side. Provides no fixation, but some support.

5. H. O Thomas' strapping, as used for dislocation of the acromio-clavicular joint (see p. 302). This steadies the clavicle and supports the weight of the arm, and is as simple and effective as any other strapping method. (Fig. 256.)

6. Bohler's clavicle splint Consists of a thick wooden wedge in the axilla, combined with local pressure from a strap over the fracture, and an attached piece to which the forearm may be tied if necessary. It is excellent in mechanical principle, but the wedge even if padded produces unpleasant pressure effects, and the whole apparatus is clumsy. It is valuable in allowing free shoulder movements in the aged, which is necessary to avoid a stiff shoulder.

7. Artificial clavicle. In this method two malleable aluminium



Fig. 252. Bohler's clavicle splint, showing the wooden wedge for the axilla, and forearm bar.

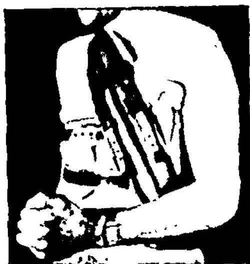
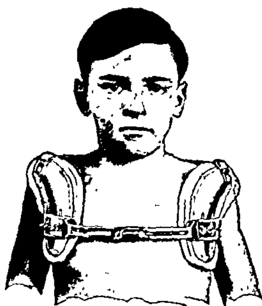


Fig. 253. Bohler's clavicle splint applied. Note axillary padding.

plates lined with felt are fitted over the anterior aspect of the point of each shoulder. These are joined anteriorly by an adjustable bar, and held in position posteriorly by flat straps crossed at the mid-line, and a wider strap joining both lower ends behind. By adjusting the length of the bar in front, and the tension in the straps posteriorly, the clavicle can be manipulated into good position and retained there. The absence of apparatus behind enables the patient to sleep on the back, and there is freedom from pressure on the fracture site, anteriorly, while the shoulder can move freely (Fig. 253).



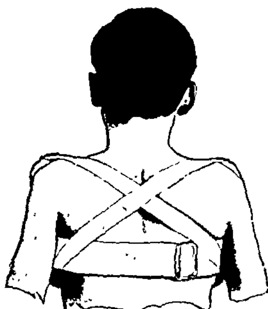


Fig 254. Artificial clavicle Front view, showing the adjustable bar, and the curved metal shoulder *caps, which do* not press on the broken bone Back view, showing the absence of apparatus, thus enabling the patient to sleep in comfort.

Fractures of either end of the clavicle. THE ACROMIAL TIP. This is nearly always due to direct violence. If the conoid and trapezoid ligaments are intact there is little displacement and the main complaint is local pain, which can be relieved by a sling, or, more certainly, by Robert Jones' strapping, which takes the weight of the limb off the injured part. Immobilisation is only necessary till pain on abduction of the arm is absent. When this lesion is combined with rupture of the conoid and trapezoid ligaments, longer rest is required (see page 649).



FIG. 255 Fracture of the outer end of the clavicle.

FRACTURE BETWEEN THE CONOID AND TRAPEZOID LIGAMENTS The clavicle is broken by depression of the shoulder and bending of the bone over the coracoid process The conoid and trapezoid ligaments maintain the fragments in position, and it is only necessary to support the weight of the arm by a sling or Robert Jones' method.

FRACTURE AT THE STERNAL END. Due to indirect violence. It is rare that the rhomboid ligament is torn, and when this occurs there is usually other severe damage as well. Unless this ligament is torn the displacement is slight, and a sling is sufficient to take the weight of the arm till healing has occurred. An interesting complication is surgical emphysema which may occur from injury to the lung. It settles down readily.

H. O Thomas' method (often called Robert Jones' method). Application The strapping is applied firmly from below the inferior

angle of the scapula of the opposite side, over a pad of felt, placed as near the root of the neck as possible (to avoid pressure on the acromion) down the anterior aspect of the arm, firmly around a pad placed over the subcutaneous border of the ulna, and then up behind, and across the upper pad, ending under the nipple of the uninjured side. It is important that the strapping be crossed as far medially on the neck as possible so that the weight falls on the



FIG 256. H. O. Thomas' or Robert Jones' strapping, correctly applied on the left shoulder, incorrectly on the right.

medial end of the clavicle. This method is particularly useful for acromio-clavicular dislocations, and the pad must leave the joint just clear at its outer edge to be sure no pressure is applied to the acromion. In fractures of the outer end of the clavicle this is not so important, as the fragments are usually in good position and only require support. The illustration exaggerates the common faults in applying this method.

1. Too thin strapping.
2. No felt pads.
3. Strapping crossed too laterally over the acromion.

The strapping works loose every four days or so and it must be

tightened up, which is done with least discomfort to the patient by passing a new strip over the old one.

LENGTH OF IMMOBILISATION. In compression and greenstick fractures in the young it need only be continued till they are free from pain. Recovery is often only a matter of days. In young people up to twenty, three weeks' rest is sufficient, and over this age, depending on the amount of pain when free movement is attempted, four to five weeks. It is not suggested that in the old complete immobilisation is continued for this time. Their greatest danger is stiffness of the shoulder, and as soon as possible active and passive movements of the joint should be commenced. They will probably need some support for the arm such as a sling for this period. Bony union always occurs in the young. In adults firm fibrous union is satisfactory.

COMPLICATIONS. 1. Excessive callus. Due to inadequate fixation, comminution, or poor reduction. Can be removed later by open operation if unsightly, but care must be taken to avoid adhesion of the scar to the bone.

2. Pain over the distribution of a supraclavicular nerve. Very rare, and due to involvement of the nerve in scar tissue. It may require section of the nerve in the supraclavicular triangle.

3. Cervical rib syndrome. Some features of pressure on the inner cord of the plexus may be caused by a dropped shoulder with gross mal-union. Reconstruction of the fracture, and resetting, or excision of part of the first rib may be necessary to relieve it.

4. Stiffness of the shoulder. This is perhaps the most common and serious complication, due to neglect to exercise the shoulder joint, which is frequently bruised in the accident. If movements of the shoulder are neglected, particularly in the old, great disability may follow. All cases should therefore be encouraged to move the supported arm daily, and as soon as pain has subsided to exercise the shoulder carefully. Retentive apparatus allowing the greatest freedom of movement should be used, the most suitable being the artificial clavicle.

5. Non-union Very rare (see Fig. 74).

FURTHER READING

KIRK. "Fractures of the Clavicle," *Am. J. Surg.*, 937, 38, 485.
GREENWOOD. "Fracture of the Clavicle," *Brit. M. J.*, 1928, 1, 1021.
YOUNG, C. S. "The Mechanics of Ambulatory Treatment of Fractures of the Clavicle," *J. Bone and Joint Surg.*, 1921, 13, 299.

CHAPTER XX

FRACTURES OF THE SCAPULA

Surgical anatomy. The scapula is so well protected by muscles, and so well supported by the thorax, from which it is cushioned by the serratus magnus and the subscapularis, that fracture is uncommon considering the size of the bone. The close attachment of muscles serves to limit displacement and minimise hæmorrhage. No important structures being closely related, complications are uncommon.

The only developmental fact of importance is the occasional failure of



FIG 257. Fracture of the body of the scapula. The fissure fracture runs from the glenoid to the vertebral border, above the *inferior* angle.

union of the acromial centres with the spine, which may be thought to be a fracture, but may be excluded by an X-ray of the opposite side, as may most developmental anomalies of bones which are almost universally bilateral.

MODE OF INJURY. Injuries fall into two broad groups, those to the processes of the bone, and those to the body. Direct violence is likely to fracture any process, or the body. Indirect violence transmitted along the arm tends to fracture the region of the glenoid, but may fracture the body by buckling it.

Sites of Scapular Fracture

1. The body, including the upper and lower angles.
2. The spine of the scapula.
3. The acromion. (a) Medial to the acromio-clavicular joint.
   (b) Lateral to the acromio-clavicular joint.

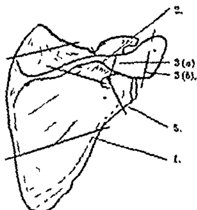


FIG. 258 The sites of fracture in the scapula. (The numbers correspond to those in the text.)

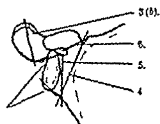


FIG. 259. The sites of fracture in the scapula, around the glenoid. (The numbers correspond to those in the text)

4. The neck of the scapula. (Anatomical.)
5. The glenoid and coracoid. (Surgical neck.)
6. The coracoid.
7. The glenoid margin.

Fractures of the body. Fracture is more frequent in the lower half of the body, and may be fissured, stellate or irregular. Owing to the fixation by subscapularis and infra-spinatus displacement is small. There is a tense even swelling below the infra-spinatus fascia. Clinically there is a story of local injury (rarely indirect) and pain. There is difficulty in raising the arm, which is very variable. Tenderness and crepitus may be elicited by grasping the lower angle of the scapula and moving the arm. In thin subjects the axillary border and vertebral border may be palpated. In fatter subjects the bone may be brought nearer the hand by elevating the shoulder and pushing backwards with the fingers in the axilla.

When the fracture is due to severe direct trauma, such as a blow

or a bullet, fractured ribs and chest complications may be seen, otherwise they are rare.

TREATMENT. This depends largely on the amount of pain, which is related to the severity of the lesion. Fixation being good, movement is to be encouraged as soon as it can be borne. In mild cases a sling for a week is sufficient. In more severe cases this must be supplemented by some form of strapping of the chest, including the infra-spinous portion of the scapula, and possibly the bandaging of the arm to the side over this. The time of retention varies from one to three weeks, and then a sling is substituted, which is worn for a corresponding shorter period. Movements of the shoulder are to be encouraged as early as possible. Very rarely there is overlap of the fragments, and this must be corrected by forced abduction of the arm, with the fingers on the axillary border to manipulate the body.

Fracture of the spine of the scapula. This can sometimes be detected by its mobility in thin patients. It is often associated with fracture of the body, and the treatment is similar.

Fracture of the acromion. Due commonly to falls on the shoulder.

(*a*) Medial to the acromio-clavicular joint. Fracture at junction of the body and spine.

(*b*) Lateral to the acromio-clavicular joint. Fracture across the broad acromial process.

In this latter case there is little displacement, and merely local tenderness, an X-ray usually being necessary to identify the fracture. The treatment is to carry the arm in a sling till pain has subsided. Shoulder movements are commenced early to avoid stiffness.

In the first and more serious condition we have a lesion which is comparable with acromio-clavicular subluxation. Usually the coraco-clavicular ligaments are intact, and there is little displacement. Two to three weeks rest in a sling will usually be sufficient treatment. Should the coraco-clavicular ligaments be torn the scapula will sink down, the condition then being comparable to acromio-clavicular dislocation, and as the ligaments are slow in healing more prolonged and firmer support by Robert Jones' strapping will be necessary. In many people the damage to the ligaments may be shown by calcification occurring in them as they heal.

Fractures of the anatomical neck of the scapula. These occur just behind the glenoid. They are almost unknown, and the treatment that of fracture of the surgical neck.

Fractures of the surgical neck of the scapula. These occur in a line running from the supra-scapular notch to the infra-glenoid tubercle. The two fractures are similar in origin and effect, except

that in the latter the arm is also deprived of the support of the coraco-brachialis, which is attached to the coracoid. There are two varieties of the lesions, depending on the severity of the accident. In the minor type, in which muscles and ligaments are not torn, there is little displacement and the lesion may be difficult to recognise. Some pain on movement of the shoulder and pain on pressure high in the axilla may be all that is found. Such cases require support for the arm for two to three weeks by a sling. Shoulder movements are actively encouraged, and at the end of six weeks there should be little disability.



FIG. 260. Fracture of the coracoid process.

In the more severe group of cases tearing of ligaments and crushing of bone allows the arm to be displaced medially, and to drop downward. The lesion may thus resemble a dislocation of the shoulder, with loss of movements, prominence of the acromion, and flattening of the deltoid, but there is no fixation of the arm. Crepitus is usually easily elicited and this emphasises the necessity for an X-ray. Other suggestive findings are the ease with which the parts are replaced and the immediate recurrence on removal of support In this the condition resembles dislocation of the shoulder with complete separation of the musculo-tendinous cuff

TREATMENT In the absence of comminution of the glenoid cavity this fracture may be treated with the arm at the side if elevation of the humerus restores the parts to position. It is slung by Robert Jones' strapping over which a circular layer is applied to keep the arm at the side. Careful watch must be kept for redisplacement

Where comminution of the glenoid is present, or upward pressure on the humerus fails to restore the parts to normal position, it is necessary to treat the arm in the abducted position. A simple extension frame attached to the side of the bed is more satisfactory than a Thomas arm, which is uncomfortable and tends to displace the parts. Traction, as shown in Fig. 152, with 6 to 10 lbs. weight

is applied. This is maintained for two to four weeks while physiotherapy is also carried out. In severe cases some limitation of the shoulder movements must be expected, and the likelihood of this increases rapidly with age.

The coracoid. Rarely fractured. Injury is due either to direct violence from which it is well protected, or muscular violence, which is usually *forced abduction*, which overstrains the pectoralis minor, or coraco-brachialis. Displacement is small, and Robert Jones' strapping applied over a pad of adhesive felt placed over the coracoid for a week is all that is necessary (*Fig.* 260).

Fracture of the glenoid. Simple chip fractures, due to indirect violence, or the pull of the long head of the triceps (Fig. 261), are usually not displaced, and can be treated by a pad in the axilla and sling, with a circular bandage over it for seven to twelve days and then slowly increasing the movements allowed, first with the arm in the sling and then without.



FIG. 261. Fracture of the inferior glenoid margin due to pull on the tubercle for the attachment of the triceps.

Comminuted fractures, usually accompanied by other fractures, must be treated by traction as described above to avoid adhesions to the glenoid surface. This is maintained for three to five weeks, and then active exercises slowly commenced. During this period massage, faradism and muscle-tensing exercises are kept up to prevent wasting and aid in avoiding stiffness of the joint.

FURTHER READING

FINDLAY, R. T. "Fractures of the Scapula and Ribs," *Am. J. Surg.*, 1937, 38, 489.

FINDLAY, R. T. "Fractures of the Scapula," *Ann. Surg.*, 1931, 93, 1001.

HITZROT and BOLLING. "*Fractures of the Neck of the Scapula*," *Ann. Surg.*, 1919, 63, 215. (Full article with further references.)

COTTON and BRICKLEY. "Treatment of Fracture of the Neck of the Scapula," *Boston Med. and Surg. J.*, 1921, 185, 326.

PFAB, B. "Die Fraktur des Proc. Coracoides." *Zentralbl. f. Chir.*, 1930, 57, 718.

that in the latter the arm is also deprived of the support of the coraco-brachialis, which is attached to the coracoid. There are two varieties of the lesions, depending on the severity of the accident. In the minor type, in which muscles and ligaments are not torn, there is little displacement and the lesion may be difficult to recognise. Some pain on movement of the shoulder and pain on pressure high in the axilla may be all that is found. Such cases require support for the arm for two to three weeks by a sling. Shoulder movements are actively encouraged, and at the end of six weeks there should be little disability.



Fig. 260. Fracture of the coracoid process.

In the more severe group of cases tearing of ligaments and crushing of bone allows the arm to be displaced medially, and to drop downward. The lesion may thus resemble a dislocation of the shoulder, with loss of movements, prominence of the acromion, and flattening of the deltoid, but there is no fixation of the arm. Crepitus is usually easily elicited and this emphasises the necessity for an X-ray. Other suggestive findings are the ease with which the parts are replaced and the immediate recurrence on removal of support In this the condition resembles dislocation of the shoulder with complete separation of the musculo-tendinous cuff.

Treatment In the absence of comminution of the glenoid cavity this fracture may be treated with the arm at the side if elevation of the humerus restores the parts to position. It is slung by Robert Jones' strapping over which a circular layer is applied to keep the arm at the side. Careful watch must be kept for redisplacement.

Where comminution of the glenoid is present, or upward pressure on the humerus fails to restore the parts to normal position, it is necessary to treat the arm in the abducted position. A simple extension frame attached to the side of the bed is more satisfactory than a Thomas arm, which is uncomfortable and tends to displace the parts. Traction, as shown in Fig. 152, with 6 to 10 lbs. weight

head to be levered over and pushed down on the stronger tissue of the shaft.

The attachment of the capsule of the shoulder joint follows the anatomical neck, except posteriorly where it passes a little lower down following the insertion of the teres minor, and so comes to overlie the epiphyseal line, making a small portion of the diaphysis intracapsular. In the specimen shown in the photograph the almost obliterated epiphyseal line may be seen, and it shows how the conical head sits on the pyramidal end of the humeral shaft, thus rendering epiphyseal separation unlikely. It will be noted that the epiphyseal line lies slightly cranial to the line of weakness in the bone.

The combined attachments of the supraspinatus, infraspinatus teres minor and subscapularis around the head of the humerus are known as the short rotator cuff. This may be avulsed in part, *e.g.*, rupture of the supraspinatus, or *in toto*, and frequently this is indicated by the avulsion of portions of the tuberosities.

Shaft. The shaft of the humerus is of the typical cylindrical build of the long bones, showing some thickening for the insertion of the deltoid on its outer aspect, running up from its mid-point. It becomes triangular below, where the medial and lateral supracondylar ridges develop, which increases its resistance to transverse strain, but weakens it to blows from in front and behind. The relationship of the radial nerve which winds around the bone, lying in contact with it for a short course above the mid-point, must be noted, and the close attachment of the brachialis anticus to the anterior aspect of the bone remembered.

Lower end. The irregular structure of the lower end provides a number of lines of weakness in the bone which is reflected in the variety of fractures met with. The prominence of the medial epicondyle grooved by the path of the ulnar nerve must be compared with the stronger lateral condyle on which the epicondyle is much less prominent.

FRACTURES OF THE UPPER END OF THE HUMERUS

General. It has already been shown that the fractures of the upper end of the humerus cannot be classified on an anatomical basis, but must be considered on the basis of internal architecture. Fractures most commonly occur at the weak line previously mentioned, but they may run obliquely so that on one side the fracture is through compact bone and on the other through cancellous bone. Because adduction is limited by the body abduction is much more commonly the position in which strain is transmitted to the shoulder from falls on the hand or elbow. From the structure of the bones it will be obvious that this results in a compression strain on the inner aspect of the bone, and a bending strain on the outer aspect of the shaft. This produces a fracture of the outer compact layer, and then a folding of the head over the sharp end of the compact bone. Owing to the curved nature of the compact layer on the inner aspect the strain is more evenly spread here, and the head tends to fold over on this as on a hinge. The opposite mechanism in the adducted position is much rarer, but accounts for a small

CHAPTER XXI

FRACTURES OF THE HUMERUS

Surgical anatomy

Development. The primary centre for the shaft appears at the end of the seventh week. Secondary centres for the head appear as follows:

Head . . .	First year.	Unite about sixth year, and fuse with the shaft at twenty to twenty-five years.
Greater tuberosity	Third year.	
Lesser tuberosity .	Fifth year.	

Secondary centres for the lower end appear as follows:

Lateral condyle .	Twelfth year.	Unite about puberty, and fuse with the shaft about seventeen years.
Capitellum . .	Third year.	
Trochlea . .	Tenth year.	

Separated by a process of the diaphysis from the.

Medial epicondyle.	Sixth year.	Fuses with shaft about eighteen years.

Upper end. From the point of view of fractures, the internal architecture of the bone is a more important guide to the site of fracture than either the anatomical or surgical neck. It is now realised that fractures cannot be classified into fractures of one or other neck. Reference to the illustration showing the bony structure of the upper end of the humerus will make this clear. The weak line in the bones, i.e., the line through cancellous bone, joining the upper ends of the compact bone of the shaft, lies midway between the anatomical neck and the surgical neck. A fracture through the anatomical neck is a fracture through cancellous bone and tends to be of the crushing or impacted type. A fracture through the compact bone of the surgical neck is difficult to produce, tends to be transverse, and resembles a fracture of the shaft. It is due to direct violence. In practice any injury is likely to be one of compression combined with leverage, and the tendency is for the cancellous tissue of the

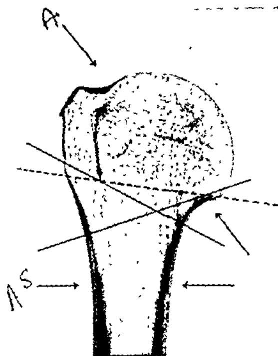


Fig. 262 Diagram illustrating the fracture sites at the upper end of the humerus The arrows indicate the surgical and anatomical necks The dotted line indicates the junction of the compact bone of the shaft and the cancellous bone of the head, while the straight lines indicate the more common directions of fracture

percentage of fractures. Fractures of the upper end of the humerus tend on the whole to show little displacement owing to this tendency to impact, and owing to the numerous tendinous insertions prolonged down the neck of the bone. Frequently neither abduction nor adduction can be recognised, and a film in the abducted position will show angulation open anteriorly or posteriorly (Figs. 263, 264).

Fractures at the level of the surgical neck are through compact bone and do not show that tendency to impact which is characteristic of fractures above. Displacement here may be classified into adduction or abduction of the head on the A.P. film, but this does not as a rule fully describe the position. The short scapular muscles tend to abduct the upper fragment, while the pectoralis major, latissimus dorsi, and teres major tend to adduct the lower fragment. The deltoid and arm muscles tend to produce shortening.

Type of violence. This is most commonly indirect from falls on the hand or elbow. Direct violence tends to produce an unimpacted fracture. Occasionally muscular pull may be responsible for fractures of the tuberosities.

Classification. It will be seen that there is no satisfactory way of grouping all fractures of the upper end of the humerus, so for purposes of discussion and record a clinical classification is recommended.

1. Impacted fractures of the upper end of the humerus. Occur through or in the region of the weak line.
2. Complete fractures of the upper end of the humerus. Tend to occur below the weak line, through compact bone, or be comminuted.
3. Fracture-dislocations of the humerus.
4. Separation of the upper epiphysis of the humerus.
5. Fractures of the greater tuberosity.
6. Ligament traction fractures (fractures of the lesser tuberosity).

It is to be noted that compound fractures in this region are rare.

Impacted Fractures of the Upper End of the Humerus

These are much more common than the complete fracture, and tend to occur in the type of individual who is liable to a Colles' fracture, the rather fat woman of over forty. It depends largely on the direction of the force whether the humerus or the radius breaks in a fall on the extended arm. The variable displacement of the head and the fracture site has been fully discussed before (Fig. 262).

Signs and symptoms. They are essentially those of the complete fracture modified by the fact that the continuity of the bone has been restored by the impaction. Pain is thus diminished, the head of the humerus rotates on rotating the forearm, and crepitus is



Fig 263. A P. radiograph of an impacted fracture of the upper end of the humerus. The greater tuberosity is separated without much displacement. In the A.P. radiograph, neither abduction nor adduction can be detected. Compare with Fig 264



Fig. 264. Radiograph of the same case as in Fig. 263. Note that this shows marked angulation of the head on the shaft of the humerus, the angulation being open posteriorly.



Fig. 265. An unusual fracture dislocation of the shoulder. After dislocation, the humerus was fractured by rotation, as is indicated by the oblique fracture. It was impossible to reduce the dislocation, owing to the loss of the humerus as a lever, and the dislocation was reduced by open operation

deformity is gross, this should be done, and the fracture treated as a complete fracture.

DIFFICULT CASES. Where there is gross displacement which has not been reduced by manipulation, whether the fracture is complete or impacted, two courses are open. Either the parts may be left as they are, or open operation resorted to. The choice of one of these methods may be difficult. In an elderly patient the result is likely to be very unsatisfactory whatever method is adopted, and it is usually best to leave the situation as it is and concentrate on function (see Fig. 266). In the very young patient unless there is gross alteration of the relationship of the head to the line of the shaft, a good functional result will be obtained. Where there is gross angulation or gross medial displacement of the lower fragment, which impinges on the glenoid, operation is carried out and the

nost suitable. Often they may be held

; plates and screws are to be avoided.

terior incision in the deltoideo-pectoral

sulcus, the deltoid being retracted laterally. If it is wished to explore the joint the attachment of the muscles to the greater tuberosity must be disturbed to expose the capsule.

PROGNOSIS. The outlook is very similar to cases of complete fracture. Though movements can be begun earlier and the results are much better in the young, the fact that the fracture is more frequent in older people reduces the generally improved results which might be expected.

Complete Fractures of the Upper End of the Humerus

SITE. The common site has been described already, together with the characteristic displacement. The fracture may be complicated by gross comminution or dislocation.



FIG. 267. Complete fracture of the upper end of the humerus X-rayed in abduction.

absent. The arm may retain much of its mobility, and it is characteristic of the patient to come for attention about forty-eight hours after the accident when the dark stain of an old hæmatoma makes its appearance at the lower borders of the deltoid.

Treatment. *The choice of treatment depends on the age of the patient and on the amount of displacement present.* In older patients



FIG. 266 Grossly impacted fracture of the upper end of the humerus. Dislocation is suggested, but the lateral X-ray shows the head to be in contact with the glenoid Treated by early movements with a fairly successful result.

it is unwise to disimpact the fracture, and in spite of apparently gross deformity it is amazing what can be achieved in the way of shoulder movement. Leaving the fracture impacted allows one to concentrate on shoulder exercises from an early date. We usually commence them two days after the injury. For this reason the arm is usually treated in the adducted position, which gives better opportunity for exercises. The abduction frame is a handicap to older people.

In younger people the question of disimpaction arises If the

deformity is gross, this should be done, and the fracture treated as a complete fracture.

DIFFICULT CASES. Where there is gross displacement which has not been reduced by manipulation, whether the fracture is complete or impacted, two courses are open. Either the parts may be left as they are, or open operation resorted to. The choice of one of these methods may be difficult. In an elderly patient the result is likely to be very unsatisfactory whatever method is adopted, and it is usually best to leave the situation as it is and concentrate on function (see Fig. 266). In the very young patient unless there is gross alteration of the relationship of the head to the line of the shaft, a good functional result will be obtained. Where there is gross angulation or gross medial displacement of the lower fragment, which impinges on the glenoid, operation is carried out and the fragments fixed as appears most suitable. Often they may be held by strong catgut, and wire; plates and screws are to be avoided. Operation is through an anterior incision in the deltoideo-pectoral sulcus, the deltoid being retracted laterally. If it is wished to explore the joint the attachment of the muscles to the greater tuberosity must be disturbed to expose the capsule.

PROGNOSIS. The outlook is very similar to cases of complete fracture. Though movements can be begun earlier and the results are much better in the young, the fact that the fracture is more frequent in older people reduces the generally improved results which might be expected.

Complete Fractures of the Upper End of the Humerus

SITE. The common site has been described already, together with the characteristic displacement. The fracture may be complicated by gross comminution or dislocation.



FIG. 267. Complete fracture of the upper end of the humerus X-rayed in abduction.

Symptoms and signs. There is a complete inability to use the arm, which is usually held by the opposite hand to prevent displacement. Pain is severe. A hæmatoma rapidly collects below the deltoid, and manifests itself by staining of the skin appearing at the lower border of the deltoid in a short time. Later the hæmatoma tracks down the arm to the elbow. The shoulder appears more rounded and swollen. If there is displacement, the deltoid may appear flattened in its lower part, but there is not the emptiness below the acromion characteristic of a dislocation. The whole arm can be displaced medially (false motion) and crepitus readily elicited. The anterior axillary fold may be deepened. Shortening is present, as measured from the acromion to the external condyle. Telescopic movement confirms what is usually a simple diagnosis. The

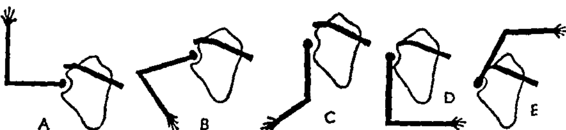


Fig. 268. The various positions of the humerus in relation to the scapula which may be useful in difficult fractures :—
A. Abduction and external rotation (" Policeman stop " position).
B. Abduction and neutral rotation.
C. Adduction and neutral rotation (hand pointing forwards).
D. Adduction and internal rotation. (In the thoraco-brachial box, a position midway between C and D is used—with the arm at a tangent to the chest.)
E. Abduction forward flexion and neutral rotation. (Zeno's position, Fig. 271.)

axillary and radial nerves are sometimes injured and the examination should include tests for this.

The differential diagnosis is from the other fractures in the region, (fractures of the glenoid and neck of the scapula), ruptures of the rotator cuff and dislocation (*q.v.*), and is usually simple.

X-ray. In all cases of fracture in the shoulder region, the usual antero-posterior film should be supplemented by a film in the lateral plane, taken from the axilla with the arm abducted. Abduction, if painful, should be obtained after the injection of local anæsthetic or under the influence of a general anæsthetic. This is very important as a case in which there is little displacement in the A.P. picture may show gross displacement in the lateral view (Figs. 263, 264).

Treatment. In many cases there is no displacement, or very little, and these cases can be retained in position by any of the following methods preferred. Where there is displacement it must be reduced by manipulation. Whatever the displacement, the most

important manœuvre is that of traction in abduction, which may be applied by traction on the forearm. This is accompanied by manipulation of the fragments by the fingers in the axilla, and varying degrees of rotation till the position is felt to be satisfactory. It is conveniently done under a screen if X-rays are available. A few fractures in which the upper fragment is adducted may require firm pressure in the axilla, such as from a fist, and strong adduction of the extended arm over this, but generally long and steady traction till the muscles relax produces reduction. Local or a general anæsthesia can be used as preferred.

Once reduced, there is considerable choice in the method of retention. The choice lies between :

1. Treatment in adduction. (*a*) Without extension. (*b*) With extension. (Robert Jones' bent-arm splint seldom used.)

2. Treatment in abduction. (*a*) Without extension. (*b*) With extension.

The debate as to whether abduction or adduction gives the best result is carried on with undiminished vigour. All shoulder injuries are liable to be followed by limitation of movement out of proportion to the damage, and it was in an endeavour to minimise these bad results that treatment in abduction was devised. Whatever method is adopted it must be remembered that freedom of movement is the object, and so early assisted active and passive movements should be begun to avoid adhesions. It is abduction, together with internal and external rotation, which is most limited in all cases. Treatment in abduction does not increase the amount of abduction possible at the shoulder, for both methods if thoroughly carried out should result in the same degree of shoulder stiffness, but it increases the amount of abduction possible by utilising the uninjured rotation of the scapula to its fullest extent. To bring the arm to the side, the stiff shoulder, treated in abduction, swings the scapula nearer the *mid-line*, and this degree of rotation is added on to the normal rotation of the scapula in full abduction. The disability is not less, but to some extent hidden and overcome. It is also a fact that a stiff abducted arm much more readily regains adduction than a stiff adducted arm abduction, owing to the assistance of gravity. For the[illegible] long as it is re[illegible] half treated, and exercises are as thoroughly carried out as when other *methods* are used. It must be remembered that the abducted position in an ambulatory patient is uncomfortable, the splint is difficult to maintain in position, and if allowed to slip may actually displace the fracture. Where, for other reasons, the patient must be in bed the position is not difficult to maintain.

Treatment in abduction is advisable in the following cases, to simplify dressing or avoid swelling :

1. Cases with severe soft tissue injury, compound fractures, or after operative reduction, or with damage to the glenoid.
2. Cases in which the fragments cannot be retained in position in adduction.
3. All cases requiring efficient extension.
4. Cases with rotator cuff injury.

METHODS OF OBTAINING ABDUCTION. *The abduction splint.* This may consist of the well-padded Cramer wire splint (see Fig. 139) or the manufactured splint which is fully adjustable. In the simpler splint the elasticity of the splint provides a rather weak extension.



FIG. 269. Bohler's splint for treatment of the arm in abduction. Front view.

In the manufactured splint of the Böhler pattern a measured tension may be applied by a spring balance. Traction may, of course, be made by strapping or skeletal traction. The application of the splint has been described earlier (see Chapter XIV).

Abduction in the recumbent position. This has usually been obtained by a Thomas arm splint which is very uncomfortable around the shoulder, due to pressure when lying on the ring. The full extension of the elbow joint is also very uncomfortable. For these reasons it has been abandoned for traction with the bent elbow by a simple apparatus such as that illustrated in Chapter XIV. A weight of 6 to 10 lbs. is usually sufficient. In certain cases, and where the apparatus described is not available, it may be advantageous to use Zeno's position. In this position the arm is held above the head with the elbow flexed, the arm fully flexed at the shoulder and midway between internal and external rotation. Strong traction can be obtained by a wire in the olecranon, with the patient's weight as counter-extension. The position is useful where the upper fragment is flexed and adducted, and where other injuries make easy access to the shoulder essential.

The length of time in the abducted position is governed by the



FIG. 270. View from above showing the hand in front of the face, and the arm brought forward from the frontal plane to relax the pull of the pectorals.

progress of the case. After a fortnight or three weeks the tendency to redisplacement has usually passed, and the extension may be slackened and gentle movements of the shoulder begun. A recumbent patient may then be put on an ambulatory splint. As far as is possible exercises to the shoulder and elbow, wrist and fingers, and active assisted movements and passive movements are continued throughout the treatment, though they cannot, of course, be carried out so early or so completely as in impacted cases. A useful criterion



FIG. 271. Zeno's position. In place of the Kirschner wire in the ... aced along the arm and ... sition is being used for

for the removal of the ambulatory splint is the return of the patient's ability to abduct the arm still further than the abduction produced by the splint, *i.e.*, lift the arm off the splint.

Varying degrees of external rotation can be applied with abduction. In the ordinary abduction splint the arm is in the neutral position. Full external rotation to 90° may be obtained by a plaster cast over chest and arm to maintain the forearm in the vertical plane. It is rarely that this is required to maintain reduction.

Avulsion of the tuberosities and short rotator cuff. In rare fracture dislocations, avulsion of the rotator cuff of the humeral head may be accompanied by fragments of the tuberosities. These come to lie between the fractured head and the glenoid (Fig. 272), open reduction and replacement offers the only chance of recovery, the prognosis in any case being poor (also see page 325).



Fig. 272. Compound fracture of the upper end of the humerus associated with complete avulsion of the bony attachments of the short rotator cuff which have prolapsed between the head of the humerus and the glenoid cavity. (*Mr. J. N. Nish's case.*)

Treatment in adduction. Where the retention is satisfactory in this position after reduction it is the method of choice. The arm is bound to the side over an axillary pad, and a sling applied to the forearm. The whole is then overlaid by a circular bandage. It is released every day for exercises from the second day, and as soon as movements can be permitted without pain the sling alone is used. With the forearm across the front of the body the arm is in almost complete internal rotation. To avoid this the Robert Jones' bent-arm splint has been used. It maintains the forearm in the neutral position. In all cases the weight of the forearm is allowed to act as a small amount of extension, but in the Jones' splint this can be increased by extension attached to the bottom of the splint, counter-traction being obtained by the pressure of the ring in the axilla. There are circumstances in which this splint may be useful, but it is difficult to apply and unsatisfactory to maintain. The position if required is best maintained by a plaster jacket with a support to hold the arm forwards (Fig. 275).

Union is rapid in fractures of the upper end of the humerus. In three to four weeks moderate callus is present, and at the end of six weeks it is firm In the young at three to four weeks the shoulder is almost back to normal. In the older people though the fracture is soundly healed there is liable to be disability due to

loss of shoulder movement, which is described later and which may persist for some months, or, in a modified form, permanently.

COMPOUND FRACTURES OF THE HUMERUS

The difficulties encountered will depend to a large extent on the amount of bone lost, and the level of the lesion. If it is low in the arm, then the upper fragment can be sufficiently well gripped by the plaster to stabilise the fracture. If the fracture is high in the arm then the shoulder must be included in the plaster for adequate fixation. The difficulties in maintaining the position of the humerus in spite of apparently adequate plasters are such that in appropriate circumstances, *e.g.*, clean open fractures, the bone should be fixed by screws or a plate.

The humerus is much more easily plastered in the conscious patient sitting up. It will however have to be done in the recumbent patient and the use of a table with a support such as that shown in Fig. 207 for cervical plasters is a help. Steadying the forearm, a wide U-shaped slab is run under the olecranon and crossed on the top of the shoulder. This can be strengthened by circular plaster bandages, and finally the forearm attached by a slab. (Fig. 273.) In simple cases of stable fracture or soft tissue injury it may only be necessary to support the forearm with a sling and a bandage over it. (Fig. 274.) In grossly unstable fractures and gun shot wounds around the shoulder a thoracobrachial plaster may be needed, but this is best applied over an underlying U slab of plaster. If its application can be postponed till the patient is conscious a much more workmanlike job will result.

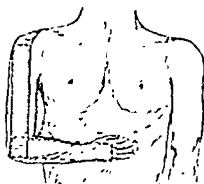


Fig. 273. Methods of fixing fractures of the humerus—fixation of the humerus by a U-shaped slab running over the shoulder. If there is an accompanying radial nerve lesion or a fracture of the forearm, a slab may be laid along the forearm as shown by the dotted lines.

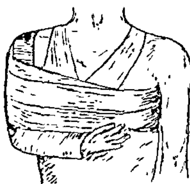


Fig 274. For simple fractures of the arm after fixation, it is sufficient to support the forearm in a sling and bandage the arm firmly to the chest with a wool pad in the axilla

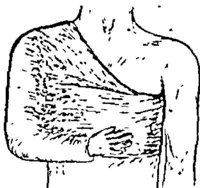


Fig. 275. In compound fractures or in fractures of the arm and forearm, the slabs are covered by plaster, padded *lightly* and moulded around the arm. The forearm can be held pointing forward if necessary.

Fracture-Dislocations of the Shoulder

The following fractures may be associated with dislocations of the shoulder.

1. Fractures of the glenoid cavity.
2. Fractures of the acromion and coracoid.
3. Fractures of the greater tuberosity.
4. Impacted fractures of the upper end of the humerus. (Very rare.)

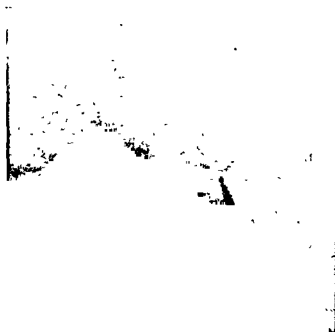


FIG. 276 Subcoracoid dislocation of the head of the humerus, with a fracture of the greater tuberosity showing displacement. The fracture was reduced by the reduction of the dislocation. Treated in abduction.

5. Complete fractures of the upper end of the humerus.
6. Avulsion fractures of the short rotator cuff.

Of these it is the last three groups which may produce difficulty.

Impaction is rare as the force must first produce dislocation and then fracture, and so it is rare for the fractured ends to be in a position in which further force can produce impaction. When present it is broken down by any effort to reduce the dislocation, and becomes the complete fracture, with resultant loss of control of the head. In such cases the only resort is to very strong traction under general anæsthesia, which is applied most satisfactorily on the Bohler arm frame, with a pin in the olecranon. Manipulation with the fingers is combined with the traction. If this fails to reduce the dislocation and the difficulties are due to a lack of control of the head of the humerus, success will occasionally be achieved by transfixing the head through the deltoid with a Steinmann's pin, which can be used as a lever to manipulate it. Failing success by this means open operation must be resorted to, which can

be conveniently carried out on the frame, which gives controlled extension. The anterior approach is used, and it may be necessary to divide the tendons of the pectoralis major and the subscapularis to restore the head to position. Once reduced the treatment is that of complete fracture, and metallic fixation may be employed if convenient. Some doubts are cast on the wisdom of using abduction in these cases, as it is thought it may produce a dislocation again, but in our experience this is a theoretical objection and treatment in abduction in the recumbent position is advised.

Fractures of the glenoid are, as a rule, little displaced, and are restored with the reduction of the dislocation. Traction is advisable to avoid adhesions in the joint, and careful early exercises are important.

Fractures of the coracoid and acromion are, as a rule, undisplaced, or only slightly displaced, and are neglected, treatment being concentrated on the shoulder.

Fractures of the greater tuberosity. Two sets of conditions may be present, either the fibrous attachments of the tuberosity are sufficient for it to move with the dislocated humerus, or they are broken and the humerus has shifted away from it. In the first case reduction of the dislocation reduces the fracture (Fig. 276). In the second group the tuberosity must be restored to position by abducting the arm or by actual open operation. Usually the position of abduction is quite satisfactory, the only disadvantage being that there is some limitation of the exercises possible at the shoulder for the first fortnight.

Complete rupture of the rotator cuff makes the reduction of the dislocation causing it quite unstable. The dislocation recurs as soon as reduced. The presence of any avulsed fragments of bone may be a guide to its occurrence (see page 325).

Separation of the Upper Epiphysis of the Humerus

Owing to the anatomical form of this epiphysis it is resistant to strains, and so displacement is rare. It does not occur after the eighteenth year. The epiphysis may be loosened or it may be completely displaced, in which case the shaft rises up *antero-laterally* and forms a bulge in the deltoid below the acromion. Reduction is necessary and is carried out by traction and manipulation as for complete fractures. Cases with no displacement can be treated with a sling and exercises from the first. Rarely in children a greenstick fracture of the upper end of the humerus occurs. Displacement is as a rule small, and it can be treated by a sling. If the displacement is gross it must be corrected.

Fractures of the Greater Tuberosity

The fracture is most commonly due to direct violence or accompanies dislocation. The tuberosity may be pulled off the head of the humerus, it may be crushed in, or it may be fragmented.

The *symptoms* and *signs* are those of other fractures in the region in which the head of the humerus can be demonstrated to be attached

to the shaft and articulating with the glenoid. Abduction is limited and particularly painful, and internal and external rotation very limited.

Clinically the cases fall into three groups :

1. Those in which the fibrous connections of the tuberosity retain it in place (Fig. 263).

2 Those in which the tuberosity is completely separated (Fig. 267)

3. Avulsion of tuberosity with short rotator cuff (Fig. 272).

The first group is treated by a short rest with the arm in a sling, and then early exercises.

The second and third groups call for abduction to restore the fragments to position, or, if this fails, open operation and pegging the fragment in place. Many authors emphasise the necessity for full external rotation in the treatment of these cases, as this movement and abduction are the most limited after the fracture. As this position is difficult to maintain and the patient is deprived of exercises by adopting it, open operation is more satisfactory if simple abduction does not retain the parts in position. The abduction splint is worn for two to three weeks, till the patient can further abduct the arm from the splint, and adhesions have formed at the fracture site.

Degenerative Tendinitis of the Short Rotator Cuff "Peri-arthritis" of the Shoulder

Late results in fractures in the shoulder region are apt to be disappointing. Adhesions in the shoulder may follow comparatively trivial injuries, and are frequently first noticed when the patient tries to move the arm after having it immobilised in a sling for such a lesion as a Colles's fracture. In such a case the sub-acromial bursa has probably been injured, slight injury here being far more likely to produce limitation of movement than slight injury to the relatively loose shoulder. Movement tends to be limited in one direction much more than others in simple adhesions, while in the more severe disabilities the loss of movement is general. Adhesions are avoided by careful exercise of the *shoulder in all cases in which this is possible.* When established they can usually be improved by manipulation and massage, if necessary the adhesion being broken down under an anæsthetic.

In many cases a serious disability will become established, particularly likely to be found in the elderly. It is characterised by gross limitation of movement in all directions, aching pain in the shoulder worse at nights, referred pain to the lower margin of the deltoid, and occasionally to the medial aspects of the arm, and tenderness over the greater tuberosity. In the early stages there may be little wasting, but later on atrophy of the deltoid is accompanied by wasting of the supraspinatus and infraspinatus, of a disuse type, which is never very gross. The clinically disappointing feature of such a case, is the total absence of radiographic findings which might account for such a degree of immobilisation. A similar condition may come on without a

history of injury, though a minor strain is the most common precipitating factor.

Postmortem examinations have shown how common are degenerative lesions of the shoulder capsule. They have also shown that in spite of this degeneration little interference with function may be present. Partial ruptures of the short rotator cuff may exert little effect on function, and for this reason unless there is evidence that the rupture is a gross one a conservative attitude should be taken up, until it is seen that recovery is not occurring rapidly, when exploration may be advised. Rupture, however, does not account for the marked fixation found clinically. This may in part be due to adhesions in the subacromial bursa, as well as in the slacker portions of the shoulder capsule.

Treatment is difficult and notoriously slow. The prognosis will depend, as far as recovery of movement is concerned, on the range of movements when first seen. Slight limitation of movement will usually be overcome, marked limitation of movement may be improved but some limitation usually remains. Treatment consists of short wave diathermy to the shoulder, massage, active and passive movements, and sometimes repeated small manipulations. Though movements may not recover pain usually disappears. A few cases complain of persistent pain. In them an acromionectomy and exploration of the subacromial bursa often relieves the disabling pain.

Differential Diagnosis between degenerative Tendinitis and Ruptures of the Short Rotator Cuff

	Tendinitis.	Rupture.
Onset	Gradual. Minor trauma.	Major trauma.
Progress	Increasing disability.	Immediate maximum disability.
Disability	Limitation of abduction external rotation. internal rotation.	Loss of control of starting movements of the shoulder (see Fig. 716).
Pain	Night pain.	No pain after initial injury pain.
Passive movement	Limited in all directions.	Full.
Active movement	Possible to a few degrees short of limitations.	Arm can only be lifted away from the side by scapula rotation.
Control	Arm can be maintained in any position inside range.	Arm can often be maintained in full abduction when this has been achieved by passive assistance.
Descent of arm	Controlled, often accompanied by a "catch" and pain.	*Uncontrolled.* Pain variable.
X-ray	Normal. Occasional calcification in floor of bursa in the young.	Occasional avulsion fractures.
Pressure	Tender over subacromial bursa.	Tender over subacromial bursa.
Arthrography	Intact shoulder capsule.	Escape of media into subacromial bursa.

FRACTURES OF THE SHAFT OF THE HUMERUS

Fractures of the shaft of the humerus are of the types affecting the long cylindrical bones, and the reader is referred to the general discussion of these in the earlier chapters, where the influence of the type of fracture, transverse, oblique or comminuted, on reduction and retention, has been fully discussed. Displacement is largely governed by the form of the fracture, and the shortening produced by the reflex contraction of muscles. The insertion of the deltoid immediately above the mid-point of the bone tends to abduct the upper fragment in fractures below the insertion, but the principal displacement found is shortening. If the fracture is above the deltoid insertion the upper fragment is adducted, while the lower fragment tends to be drawn up and outward (Fig. 278).

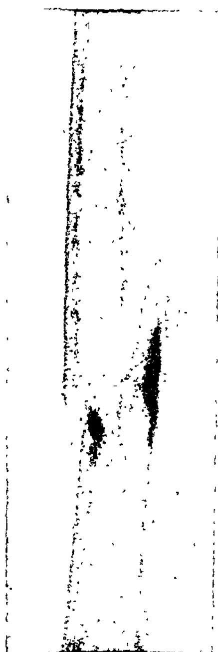


FIG. 277. Typical spiral or helical fracture of the humerus.

DIAGNOSIS. This is as a rule very simple, as false motion can be so easily detected. The arm is completely powerless, and the forearm held by the opposite hand. To measure for shortening is rarely necessary, but certain spiral fractures and greenstick fractures may give rise to local pain only, with no abnormal mobility, in which case measurement may help, but recourse to an X-ray is usually necessary.

COMPLICATIONS. 1. Injury to the radial nerve. The nerve may be concussed, attenuated, or bruised, which will produce incomplete and rapidly recovering symptoms. It may be crushed, partially or completely divided. In the former instances the lesion will be partial, or show early recovery. In the last instance the paralysis will be complete, the reaction of degeneration will set in within three weeks, and operation is indicated to suture the damaged

nerve at an early date, usually as soon as one has made up one's mind that the lesion is complete. (For late involvement see p. 330.)

2. Injury to the median and ulnar nerves is very rare, and usually incomplete.

3. Injury to the brachial artery is uncommon, but important (see p. 56).



Fig. 278. Fracture of the shaft of the humerus above the level of the insertion of the deltoid, with shortening and medial displacement of the upper fragment.



Fig. 279. The same case reduced after cutting both surfaces obliquely; fixed by two screws. Excessive new bone formation in the intermuscular planes. Excellent functional result.

Treatment. The difficulty met varies with the type of fracture. Spiral fractures tend to shorten, and not to displace. Transverse fractures tend to displace, but if reduced not to shorten. Treatment is therefore adjusted to meet the varying tendencies to redisplace, bearing in mind that slight angulation, and even moderate lateral displacement are not serious in the arm, as we are not concerned with joint pressures under body weight. Even shortening up to 1 inch is scarcely noticed.

Upper third. In all cases it is the upper fragment which is most

FRACTURES OF THE SHAFT OF THE HUMERUS

Fractures of the shaft of the humerus are of the types affecting the long cylindrical bones, and the reader is referred to the general discussion of these in the earlier chapters, where the influence of the type of fracture, transverse, oblique or comminuted, on reduction and retention, has been fully discussed. Displacement is largely governed by the form of the fracture, and the shortening produced by the reflex contraction of muscles The insertion of the deltoid immediately above the mid-point of the bone tends to abduct the upper fragment in fractures below the insertion, but the principal displacement found is shortening. If the fracture is above the deltoid insertion the upper fragment is adducted, while the lower fragment tends to be drawn up and outward (Fig. 278).

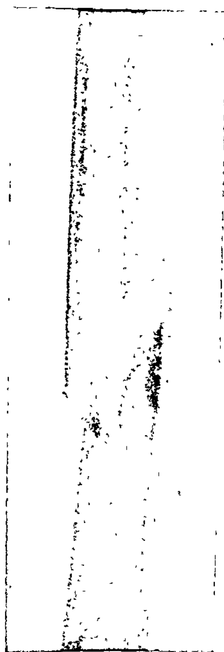


FIG. 277 Typical spiral or helical fracture of the humerus.

DIAGNOSIS. This is as a rule very simple, as false motion can be so easily detected. The arm is completely powerless, and the forearm held by the opposite hand. To measure for shortening is rarely necessary, but certain spiral fractures and greenstick fractures may give rise to local pain only, with no abnormal mobility, in which case measurement may help, but recourse to an X-ray is usually necessary

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nerve at an early date, usually as soon as one has made up one's mind that the lesion is complete. (For late involvement see p. 330.)

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Treatment. The difficulty met varies with the type of fracture. Spiral fractures tend to shorten, and not to displace. Transverse fractures tend to displace, but if reduced not to shorten. Treatment is therefore adjusted to meet the varying tendencies to redisplace, bearing in mind that slight angulation, and even moderate lateral displacement are not serious in the arm, as we are not concerned with joint pressures under body weight. Even shortening up to 1 inch is scarcely noticed

Upper third. In all cases it is the upper fragment which is most

difficult to control. In fractures of the upper third, treatment is similar to that of fractures of the upper end of the humerus.

Owing to the fibrous attachments around the bone displacement is infrequent and when it occurs is as a rule readily reduced. The chief difficulty met with is angulation, open medially. Owing to the impossibility of controlling the short upper fragment, unless a spike is inserted into it, it is usually necessary to bring the arm into alignment with the upper portion, and this means treatment in abduction. A short period of traction (light) in recumbency till swelling has subsided may be helpful. Ambulatory abduction splints require considerable attention, and are troublesome to the patient, but may be effectively employed if the *precautions previously outlined* are taken. A failure to reduce the deformity or to overcome marked angulation is an indication for open operation, through an anterior approach and reflecting the deltoid from the clavicle and acromion. It is particularly in the difficult fracture at the junction of the upper and middle third of the shaft that the tendency to non-union is most marked, partly because of the difficulty in immobilising the parts, and partly because of the frequent interposition of muscle. These fractures should be treated seriously in the first weeks by light skeletal traction in bed with lateral plaster slabs If it is impossible to bring the ends into contact satisfactorily after manipulation, no hesitation should be felt in doing this by operation. The most satisfactory procedure is to cut both of the fractured surfaces obliquely and screw them together (Fig. 279). Union is rapid and the extra stability enables active exercises to be carried out sooner. Slight angulation and slight shortening is no serious handicap. Plating may be used if desired.



FIG. 280 Comminuted transverse fracture of the shaft of the humerus in lower third after reduction treated by a U-shaped slab A classical example of fracture by bending (See Fig. 8)

LOWER TWO-THIRDS Here control of angulation with lateral splints is much more satisfactory, as they exert some influence on the upper fragment. The chief difficulties are likely to arise from lateral displacement or shortening, but unless these are marked they should not cause concern. The weight of the forearm is sufficient to

exert some traction on the arm, and this is increased by the weight of the plaster (Hanging Plaster method). Control of the fragments will best be obtained by a U-shaped slab, which is commenced on the inside of the arm at the lower border of the axilla and then carried around the olecranon and up to the acromion. In acute cases in which swelling is likely to occur, or has occurred and will necessitate replaster soon, it will be sufficient to bandage this slab on with a wet gauze bandage, place the forearm in a sling and bandage the whole to the side (Fig. 273). As soon as the swelling has subsided, and the acute pain of the fracture is no longer present, a more permanent plaster including the forearm is applied. This is most conveniently done in the sitting position, so that gravity assists in straightening the arm. The shoulder may be supported from above and the hand should rest on a table of the appropriate height. If desired the fracture can be infiltrated with a little novocaine and the extension increased by hanging a weight on the forearm. The U-shaped slab is applied as before (Fig. 275) and then arm and forearm completely included in plaster. In cases in which all movement at the fracture site must be stopped, *e.g.*, suspected non-union, the arm plaster may be attached to the thorax by circular plaster bandages. In most cases a sling with a circular bandage over it is sufficient.

COMPOUND FRACTURES. See page 321.

PROGNOSIS. Fractures of the shaft of the humerus have an unenviable reputation for non-union, which is due to several factors. Firstly, the close association of muscle fibres with the bone, which tend to catch between the ends, and so separate the bone ends. Secondly, the difficulty in immobilising the upper fragment of the humerus. And, thirdly, the ease with which shearing strains are developed from the rotation of the forearm.

These difficulties are met in the transverse fracture



FIG. 281. Extensive formation of callus, which involved the radial nerve.

only, particularly in the young. The lines of treatment have been suggested already, by which such a complication can be avoided. Where it has arisen Beck's bone drilling may occasionally be satisfactory, though owing to the risk of damage to nerves and vessels it is usually necessary to do it through an incision exposing the bone. If this is necessary it seems worth while going a little further and either trimming the ends obliquely and screwing them together or applying an onlay graft.

Oblique fractures unite rapidly and are firm in three weeks in the young and in four weeks in the older patients. In the transverse fractures union is firm in five weeks in the young and six to eight in the old. Mal-union is less of a disability in the upper extremity than in the lower and rarely gives trouble.

Late involvement of the radial nerve. In certain cases there is an onset of a radial palsy ten to fourteen days after the accident. Though there has been much debate as to whether the nerve is pressed on by callus or not, there seems to be no doubt that it may be. Such cases are best left three months before exploration, during which time there is often spontaneous recovery. If this does not occur the nerve is explored and freed.

Some people explore earlier than this, on the ground that it can do no harm. With this one is in agreement, but one has seen several cases recover completely, when the recovery has only commenced in the fifth month, and so by waiting operation has been avoided. Each case must be judged on its merits and is at present treated according to the views of the individual surgeon. The paralysis in such a case may be complete, and confusion with a complete division of the nerve at the time of injury which requires early operation will be made if all cases are not tested for a nerve lesion as soon as seen. Many people try to explain the late radial lesion on the assumption that it has been present since the injury and overlooked. This explanation is quite certainly wrong, but it emphasises the importance of early and complete neurological examination.

FRACTURES OF THE LOWER END OF THE HUMERUS

Classification. (*a*) Complete fractures of the lower end of the humerus.

1. Flexion fractures. (Rare)
2. T-shaped fractures
3. Extension fractures.
4. Supra-condylar fractures and epiphyseal separations.

(*b*) Incomplete fractures of the lower end of the humerus.

1. Fracture of the lateral epicondyle.
2. Fracture of the lateral condyle and capitellum.

Fig. 282. The fracture sites at the lower end of the humerus.
A. Fracture of the lateral epicondyle.
B. Fracture of the lateral condyle.
C. Fracture of the medial condyle.
D. Fracture of the medial epicondyle.
E. F. The line of T-shaped (flexion) fractures.
G. Supra condylar fractures.

3. Separation of the lateral epiphysis. (Capitellar.)
4. Fracture of the medial condyle.
5. Fracture of the medial epicondyle.
6. Separation of the medial epiphysis.

In all fractures of the elbow region, swelling is apt to be rapid and severe. For this reason early diagnosis and treatment are

Fig. 283 The method of examination of the bony points around the elbow.

advisable Great care must be taken that the circulation is not interfered with, and circular plaster bandages or acute flexion are to be avoided. To reduce the swelling, recumbency, or Zeno's method of treatment are very useful, and should be practised in all severe cases for the first few days. The median, ulnar, and radial nerves are liable to be involved on occasions, and must be carefully examined in every case.

In examining the region the relationship of the lateral and medial epicondyle and the tip of the olecranon are all important. *In extension they are in line*, though the tip of the olecranon lies ½ inch nearer to the medial epicondyle. In flexion the three points form an almost equilateral triangle. Increase in separation of the epicondyles must be judged by comparison with the opposite side.

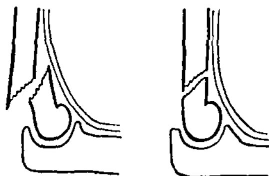


FIG. 284. Flexion fracture of the lower end of the humerus.

Flexion and T-shaped Fractures

MECHANISM. Due to falls on the flexed elbow, the olecranon or upper part of the ulna striking the ground first. T-shaped fractures are flexion fractures in which the violence has split the lower fragment.

The lower end of the humerus is broken across in a line running obliquely downward and backward. A sharp spicule is thus left posteriorly which may protrude through the triceps and produce an indirect compound fracture. The small distal fragment tends to be displaced upward and forward, which does not interfere with flexion.

INCIDENCE. Confusing figures are given owing to a failure to separate adult from children's figures. Extension fractures are most common in children (supra-condylar) and less common in adults, where the extension strain produces a posterior dislocation of the elbow. Flexion fractures are more common in adults and less common in children, and in adults the lower fragment is commonly comminuted, producing the T-shaped fracture.

DIAGNOSIS. The patient has lost the use of the forearm, and holds it with the hand of the opposite side. The deformity tends to resemble that of a dislocation of the elbow, the forearm appearing lengthened. The three bony points of the elbow are in their

normal relationship, and occasionally the spicule of the humerus may be felt as a fourth. False motion of the forearm forwards is free, but backwards is limited.

Treatment. REDUCTION is readily accomplished as follows. A general or local anæsthetic is used. Manipulations are easier with the patient sitting which is an advantage favouring local anæsthesia. The arm is fixed by an assistant. Grasping the forearm firmly with both hands and with the thumbs in the cubital fossa and the fingers on the epicondyles and fracture site, the elbow is flexed to a right angle and then strong pressure made in the line of the humerus, to restore the length of the bone. When this has been done the forearm and the lower fragment are pushed directly backwards, where they should engage firmly.

RETENTION in this type of fracture is not as a rule as easy as in extension fractures, but slight deformity is not so important as it is in the latter. A plaster gutter splint with the arm at right angles and the slab applied to the anterior aspect of the arm will be satisfactory in most cases, but in a few this will fail. The alternatives, then, are extension with a pin in the olecranon, which is maintained till early union has occurred, or a plaster gutter splint with an extended elbow, which is very satisfactory in children. The reluctance to use this position is unnecessary. Children, and to a less extent adults, regain flexion as easily as extension. There is no risk of swelling causing pressure, and in this position radiography gives one a more accurate idea of the position of the parts.

Union occurs rapidly, in children in three to four weeks, and in adults in four to five weeks. While exercises to uninvolved joints are to be ecnouraged, it is important to keep the elbow at rest so long as resolution is occurring. There is a tendency for ossific deposits to occur around the elbow in the muscles and in any hæmatoma present, and this is encouraged by any further trauma to the region from early movement. After adequate immobilisation as outlined, the arm is carried in a sling, and gentle active movements which do not produce pain encouraged. When these are free the sling is abandoned. At no period are passive stretching exercises or strong active exercises, to be used. These inevitably increase the stiffness of the joint. To measure the amount of improvement in movement of the joint some form of angle measuring instrument (or goniometer) is important, and a convenient type is illustrated in Fig 145

In children, even with remarkable displacements, the return of function is good, but in adults there is liable to be permanent limitation Where limitation occurs in children one of the complications outlined later has usually occurred.



Fig. 285. T-shaped fracture into the elbow joint. Antero posterior view.

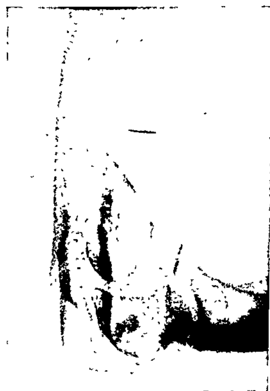


Fig. 286. Lateral view of same case.



Fig. 287. Same case as previous figure under olecranon skeletal traction with a bent elbow. Lateral view.



Fig. 288. Same case as previous figure showing the final result in the antero-posterior X-ray.

T-shaped fractures. The fragments are frequently grossly misplaced, and appear to lie in a pool of blood in which manipulation becomes uncertain and retention impossible. Full return of function of the elbow demands accurate reconstruction of the lower end of the humerus. Even at open operation this may be difficult. Treatment by traction with a pin through the olecranon and the elbow held at a right angle will generally get the fragments into good position and maintain them there. If the position is unsatisfactory at first the fragments are manipulated under anæsthesia. A very convenient apparatus for maintaining traction with the elbow flexed is that described in Chapter XIV. It is comfortable for the patient, adaptable to many positions, and comparatively simple and cheap. Treatment should be commenced at the earliest possible moment and this is particularly so in children, in whom callus rapidly forms. Failure to obtain satisfactory position at the end of a week by this method demands open operation through a posterior approach. The use of metal retentive apparatus is advised in adults but in children suture with strong catgut after drilling the bones is best.

Extension Fractures, Supra-condylar Fractures, and Complete Epiphyseal Separations

In EXTENSION FRACTURES the line of fracture runs from behind, downwards and forwards, leaving a sharp spicule of bone anteriorly, which is liable to be pushed into the cubital fossa. It is less inclined to produce indirect compound fracture than the spicule in flexion fractures. In children the obliquity tends to be less marked, and the separation less complete. Many supra-condylar fractures are really transverse, and of the greenstick variety. The short distal fragment is commonly displaced backwards (74 per cent.), and if detached this displacement is increased by the pull of the triceps Displacement may be marked, indicating severe periosteal damage, with the formation of a large hæmatoma. This is important, as it may lead to ossific deposits outside the usual limits. The capsule is attached above the epiphyseal line and so the joint is inevitably involved in epiphyseal separations, and almost inevitably so in supra-condylar fractures

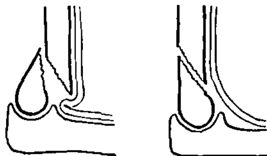


FIG. 289. Extension fracture of the lower end of the humerus, showing the manner in which the brachial artery may be pressed upon.

EPIPHYSEAL SEPARATIONS. The separation of the conjoined epiphyses as a unit can only occur before the trochlear portion of the diaphysis has grown down between the epiphyses for the medial and lateral condyles. It therefore does not occur after the fifth year. The mechanism and displacement

is essentially the same as a supra-condylar fracture, the separation occurring on the metaphyseal side of the cartilage.

DIAGNOSIS. The ease of diagnosis depends on the separation of the fragments. At one end of the scale we have the child in whom no deformity is visible, very little bruising, and slight tenderness in a line above the condyles combined with a reluctance to use the limb. At the other end of the scale is the adult in whom the condition resembles a posterior dislocation of the elbow, with gross deformity, apparent shortening of the forearm, and prominence of the olecranon behind. False movement at the fracture site is generally easily elicited, though swelling may be so great as to obscure the usual bony landmarks.



FIG. 290 Extension fracture of the lower end of the humerus united with posterior displacement.

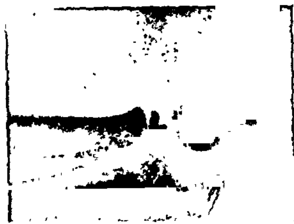


FIG. 291. Supra-condylar fracture of the lower end of the humerus.

Supra-condylar fractures being so common in children it is the age of the patient which gives the clue to the diagnosis in most cases.

Treatment. Cases in which there is no displacement (22 per cent.) and little swelling may be treated by a cuff and collar for two weeks, a sling for a week, and then active movements. As there is no periosteal tearing there is no fear of excessive ossification in the surrounding tissues from comparatively early use.

When there is displacement it should be reduced. It only takes a moment with firm pressure of the thumbs over the lower end of the humerus to restore the part to normal if there is no tension in the soft parts, and it can usually be felt to grate as it returns to position, and when in position full flexion of the elbow can, and must, be obtained.

In children there is little tendency to recurrence. Acute flexion, the "natural splint position," has been recommended for this fracture as the ideal method of retention. In most cases the fragment stays in position easily, and the right-angle position is more comfortable and less worrying. A posterior plaster gutter splint and a sling for three weeks, followed by a sling only for a week or two, is usually quite satisfactory.

It is in the older children or in adults that trouble arises from difficulty in reduction, due to a tense hæmatoma around the fragments and incomplete reduction is followed by difficulty in retaining



FIG. 292. Reduction of an extension fracture of the lower end of the humerus.

the fracture in position. Retention may be found easy when the arm is put into acute flexion and the triceps made to act as a splint, but such a position must be most carefully watched owing to the risk of vascular obstruction. In the majority of patients the position with the arm in a posterior gutter splint and held at right angles is satisfactory When neither of these methods suffice in adults one must use skeletal traction with a pin in the olecranon and the elbow at right angles. At the end of four weeks the plaster or other support can be discarded, and the arm is then carried in a sling for two weeks. Flexion is encouraged in the sling, but active extension is not allowed till the sling is removed in the sixth week. In children it is better to fix the limb temporarily and wait till swelling has subsided, when reduction can usually be achieved. Too much time must not be allowed to elapse between attempts, as union is rapid. Failure to

obtain perfect position (Fig. 200), is not followed by any untoward result, the humerus remodelling itself in the young to allow full flexion.

Very rarely operative reduction is necessary. This is done through a straight posterior incision. Fixation by olecranon traction and plaster or plaster alone follows, and as in all cases in which it is desired to get rid of swelling around the elbow early use of an abduction splint or Zeno's position is made. In Zeno's method the forearm is hung over the chest in a sling, while traction is exerted in the line of the humerus by the wire in the olecranon (Fig. 271). If the arm has been plastered without the use of a Kirschner wire strapping is attached to the arm portion of the plaster.

In both extension and flexion fractures there has been considerable discussion as to the influence of pronation and supination on the lower fragment. The only possible movement of the lower fragment on a fixed forearm is flexion and extension. Certainly the adduction and abduction of the lower fragment can be controlled by the pronation and supination of the forearm, but this is due to rotation developed around the central line of the forearm, and not due to relaxation of muscles. The best position of the forearm is that of mid-pronation.

Incomplete Fractures of the Lower End of the Humerus

Fractures of the lateral epicondyle. This is an uncommon lesion owing to the lack of prominence of the lateral compared with the medial epicondyle. In either fracture the mechanism is similar.

(*a*) Due to direct violence.

(*b*) Due to adduction (or abduction) strains of the extended elbow, when the tensed extensor (or flexor) group of muscles pulls off the epicondyle.

(*c*) In association with a dislocation of the elbow.

CLINICAL FEATURES. In fractures of either epicondyle there is usually little displacement. The chief features are local pain and bruising. The bruising may extend down the group of muscles attached to the epicondyle, and result in pain and paresis of the group. There is a variable amount of effusion into the elbow, and limitation of movement. In cases with no displacement the X-ray distinguishes the condition from a severe bruise.

DIFFERENTIAL DIAGNOSIS. Old fractures may fail to unite, and be regarded as a recent lesion, but the layer of compact bone on the supposed fractured surface in old lesions shows the condition to be of some standing. In fractures of the medial epicondyle the epiphyseal line, which is usually much more even than the fissure of a

In children there is little tendency to recurrence. Acute flexion, the "natural splint position," has been recommended for this fracture as the ideal method of retention. In most cases the fragment stays in position easily, and the right-angle position is more comfortable and less worrying. A posterior plaster gutter splint and a sling for three weeks, followed by a sling only for a week or two, is usually quite satisfactory.

It is in the older children or in adults that trouble arises from difficulty in reduction, due to a tense hæmatoma around the fragments and incomplete reduction is followed by difficulty in retaining



Fig. 292. Reduction of an extension fracture of the lower end of the humerus.

the fracture in position Retention may be found easy when the arm is put into acute flexion and the triceps made to act as a splint, but such a position must be most carefully watched owing to the risk of vascular obstruction. In the majority of patients the position with the arm in a posterior gutter splint and held at right angles is satisfactory When neither of these methods suffice in adults one must use skeletal traction with a pin in the olecranon and the elbow at right angles At the end of four weeks the plaster or other support can be discarded, and the arm is then carried in a sling for two weeks. Flexion is encouraged in the sling, but active extension is not allowed till the sling is removed in the sixth week In children it is better to fix the limb temporarily and wait till swelling has subsided, when reduction can usually be achieved. Too much time must not be allowed to elapse between attempts, as union is rapid. Failure to

which a sharp edge is struck by the condyle, may cause the condition, and fractures from severe adduction strain may involve the condyle rather than the epicondyle. The fracture runs from the lateral epicondylar ridge to the medial aspect of the capitellum. Displacement of the fragment with the extended and abducted arm tends to be out and up, and with the adducted arm down and inwards. It is important to remember that in cases associated with dislocation of the head of the radius the capitellum remains attached to the head of the radius and moves with it.

Diagnosis. The symptoms are those of severe injury to the

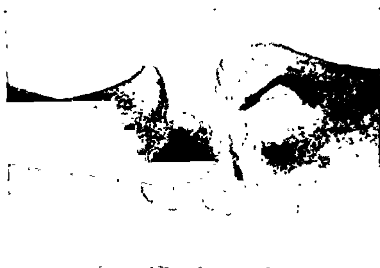


Fig 294. Fracture of the lateral condyle of the humerus with posterior dislocation of the head of the radius, to which it has remained attached.

epicondyle, together with increased lateral movement at the elbow joint, which is distended with blood. The lower end of the humerus is broadened, and the lateral condyle can be moved separately in an A.P. plane with the production of crepitus. It is important to note that dislocation of the head of the radius from the upper radio-ulnar joint and lateral dislocation of both bones of the forearm are common accompaniments of the lesion, and must be excluded by careful lateral and A.P. X-rays.

Treatment. Cases may be grouped into those with, and without, displacement. In cases without displacement the ligamentous attachments of the condyle are holding it in place, and relaxation by a high sling or collar and cuff for two to three weeks will be sufficient. Where the displacement is slight and accompanied by swelling, a dorsal plaster gutter splint with the arm at right angles will be better. Exercises are begun at the end of three to four weeks.

Displacement varies. It may be: (1) Posterior, accompanying

fracture, may cause confusion. An X-ray of the opposite side may aid in distinguishing the condition, but in the absence of displacement an X-ray later which may show the presence of callus is the only proof available that there was a lesion through the epiphyseal line. If the case is clinically a separated epiphysis it is best treated as such in spite of negative X-ray evidence.

Another cause of difficulty are plates of ossified tissue which may occur in the fibrous intermuscular septa of the flexor and extensor muscle groups. These are usually multiple and bilateral. They show a well organised periphery (Figs. 293, 307).



FIG. 293 Ossification in the intermuscular septa attached to the medial epicondyle of the humerus.

Bony deposits in the tissues of osteo-arthritic elbows, or ossifications in hæmatomas after old injuries, may occasionally be confusing.

Treatment. In cases without displacement a sling is sufficient till the pain has gone. In cases with displacement, longer rest is necessary as there is associated damage to the joint, but there is very rarely the necessity to peg the fragment back into position, seen with the medial epicondyle. After four weeks, gentle exercises in the sling are commenced and this is abandoned in a week. Full function is restored in five to six weeks, there being, as a rule, no disability.

Fracture of the lateral condyle (and capitellum). In children from the age of six to fourteen an essentially similar lesion is a fracture separation of the lateral epiphysis. Separation is on the metaphyseal side, and usually takes a flake of bone with it. The diagnosis and treatment is similar to the adult condition.

TYPE OF INJURY. The fracture is most commonly due to falls on the extended or partly flexed arm, in which the force is transmitted along the radius, and so may be associated with fracture of the head of the radius. Direct injury, such as may occur in falls, in

of the head of the radius. It may vary in size, and, unless large, is usually overlooked, even in the X-ray, owing to it being largely cartilaginous. Later locking and arthritic symptoms develop as it forms a loose body in the joint, or attaches itself in a situation limiting movement (osteochondritis dessicans of the elbow). The immediate symptoms of the lesion are effusion into the elbow, with variable pain, limitation of movement, and some pain on pronation and supination. These may be very slight. It is usually diagnosed on the X-ray findings.

Treatment. Large fragments frequently remain in good position and should be left; the elbow being rested in a plaster. Smaller fragments, if noticeable on the radiograph, are usually displaced and lying loose in the joint. They should be removed. Occasionally the anterior half of the



FIG. 297. Cohn's lines showing the normal relation of the capitellar epiphysis to a line along the anterior surface of the humerus, and one parallel to this through the centre of the shaft.

capitellum is sheared off and displaced upwards (Fig. 296). It should be reduced by open operation and can usually be retained in position by flexion of the elbow. Satisfactory union follows.

Separation of the capitellar epiphysis. This occurs in children up to the age of ten, before the capitellar epiphysis fuses with the other epiphyses to form the lateral epiphysis, whose separation is similar. In separation of the epiphysis of the capitellum alone the cartilaginous structure of the lateral condyle and the trochlear are involved, but they are not shown in the X-ray film.

The injury may occur in the same way as that to the lateral condyle. Displacement may occur backwards, forwards, or laterally, or these displacements may be combined, which is usually the case.

SYMPTOMS. These resemble supra-condylar fracture. Suspicion may be aroused by noting that there is a slight lateral dislocation of the forearm, in cases seen before swelling has occurred. In most cases the differential diagnosis from supra-condylar fracture depends on the X-ray. In spite of good X-rays careful examination of films is necessary to distinguish the lesion



FIG. 295. Fracture of the lateral condyle of the humerus with rotation so that the fracture surface looks outwards.

the head of the radius; (2) Rotation, so that the fractured surface looks laterally. (3) Varying displacements to a lesser degree. Reduction must be attempted under local or general anæsthesia. In the first group reduction of the radio-ulnar dislocation reduces the fracture as well. The second group may be difficult, and usually require operative replacement, but they may be replaced by manipulation of the fragment, especially if the case is seen early before gross swelling has occurred. After replacement retention is often more satisfactory with the arm extended. Similar principles apply to the third group in which replacement by manipulation is usually not difficult. Retention is by a plaster gutter splint, with the elbow at right angles, where possible, for three to four weeks, followed by a sling for a fortnight, after which gentle movements are begun.

OPERATION. The approach is best made through a posterior incision, and the triceps retracted till the fractured surface is seen. When the clot is cleared away the twisted condyle may be readily untwisted and restored to position. It is drilled with a fine hand awl, and corresponding drill holes made in the shaft of the humerus. These are then threaded with catgut which is firmly tied. After operation the arm is put on a posterior plaster slab with the elbow at right angles, and the joint is moved at the same time as the cases treated non-operatively.

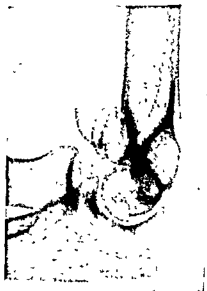


FIG 296. Fracture of the capitellum, resulting in upward displacement of a hemispherical fragment of bone.

Fractures of the capitellum. In this not uncommon condition, a flake of bone may be knocked off the round surface of the capitellum by the impact of the head of the radius and may be associated with fracture

and this demands a knowledge of the normal relations of the epiphysis to the diaphysis. In the antero posterior film the capitellar centre appears as a triangular shadow, with a sloping upper surface lying against the diaphysis. The outer edge is slightly curved and lies distinctly medial to a line joining the lateral epicondyle and the head of the radius in a true A.P. film (Fig. 301). The upper end of the ulna when the arm is extended overlaps the medial end of the capitellar shadow. According to the direction of the chief displacement so the lateral or the A.P. X-ray gives the most information. In the lateral

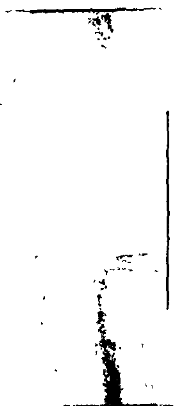


FIG. 302 Antero posterior view of the elbow after reduction.

film of the normal arm the epiphysis is seen as a rounded shadow lying below the shaft of the humerus and in front of it. This can be best *shown* by prolonging two lines through the epiphysis. The first runs down the anterior surface of the humerus The second is a line parallel to the first through the *centre* of the shaft Up to the age of nine the epiphysis lies behind the anterior line. After the ninth year two thirds of the epiphysis *is in front* of it, while the whole epiphysis is in front of the posterior line (Fig. 297).

In lateral displacement there are two points to look for:

1. The outer edge of the epiphysis is now nearer the line joining the lateral condyle and the head of the radius.

2. The ulna shadow, unless the bone is dislocated, lies free of the shadow of the capitellar centre, or just over its edge (*Fig. 300*).

In anterior displacements the epiphysis may lie in front of the anterior line but most often it is only moved a small distance in front of the posterior line, which runs down the centre of the shaft.

For these comparisons accurate films in the A.P. plane and the lateral plane are required, with the elbow *completely* extended in the A.P. film and

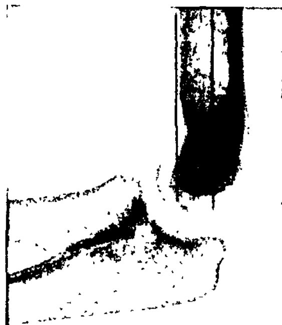


Fig. 298. Slight posterior displacement of the capitellar epiphysis.



Fig. 299. Lateral displacement of the capitellar epiphysis. Lateral view showing the slight associated posterior displacement.



Fig. 300. Antero-posterior view showing the lateral displacement of the epiphysis

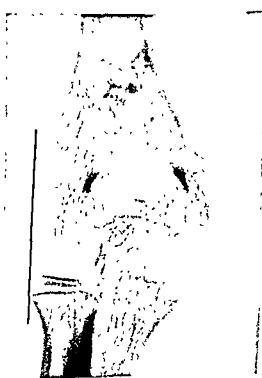


Fig. 301. Antero posterior view of the normal elbow for comparison.

tendency for the epiphyses to redisplace, and a cuff and collar is [illegible] for retention. In two to three weeks a sling is used and movements allowed [illegible] made this, and it is discarded a week later. In a correctly reduced case there is no disability. In cases which are neglected there is loss of extension.

Fractures of the medial condyle. The mechanism is essentially similar to that of fractures of the lateral condyle. The associated dislocations of the elbow are posterior and medial. The line of the fracture runs up from the just lateral to the trochlea almost vertically



Fig. 305. Fracture of the medial condyle of the humerus into the trochlea.



Fig. 306. A fracture of the medial humeral condyle of the type shown in Fig. 305 accurately plated by Lane.

to the medial supra-condylar ridge. From the mechanics of the injury it can be seen that the ulna will frequently be displaced medially with the fragment. Dislocation of the head of the radius may be associated. Symptoms are comparable to those of lesions of the lateral condyle. Displacement tends to be greater owing to the disturbance of the ulna, and there may be symptoms of ulnar nerve pressure. If the head of the radius is dislocated in addition to the dislocation of the ulna the elbow is quite unstable after reduction and requires both extension and lateral pressure to control it. If the ulna alone is dislocated the displaced condyle can usually be restored to a stable position. Treatment will be along the following lines.

1. No displacement. Posterior gutter splint, three to four weeks. Sling, two weeks.

flexed in the lateral view. Comparative pictures of the opposite side are useful. Flexion of the elbow alters the relation of the ulna shadow to the capitellar centre, but does not alter the relation of the capitellar centre to the humerus, and if extension cannot be obtained the humerus must be kept parallel with the plate that this observation at least is accurate. Films for



FIG. 303. Anterior displacement of the capitellar epiphysis.

comparison must be made with the sound elbow at the same angle as the injured one.

Treatment. Reduction is by manipulation. In posterior displacements full firm flexion of the elbow is made, while gentle forced hyper-extension of the elbow reduces anterior displacements. In lateral displacements lateral pressure is required, and can be easily applied by a narrow padded board, which is firmly pressed into the flexed elbow as it lies on its inner side, between the lateral condyle and the head of the radius (Fig. 304). There is no



FIG. 304. The reduction of lateral displacements of the capitellar epiphysis.

reduction of the elbow after the accident and the small fragment of the medial epicondyle is caught between the sigmoid notch of the ulna and the trochlea, where it may be easily overlooked with grave consequences later (see p 661 and Fig 308)

DIAGNOSIS. The symptoms are comparable to those of the lateral epicondylar lesion The flexor group of muscles may be weakened with inability to fully flex the fingers Characteristic



FIG. 309 Fracture of the medial epicondyle with displacement of the epicondyle into the joint. Lateral view.



FIG 310 Fracture of the medial condyle with displacement into the joint Antero posterior view, showing the epicondyle lying between the trochlea surface of the humerus and the sigmoid notch of the ulna. (Same case as Fig 309.)

bruising extending down the flexor pronator group of muscles may be seen. The ulnar nerve is damaged to a variable degree in most cases, and in the case where the fragment has been displaced into the joint there is always a temporary complete lesion. In these cases hæmorrhage may obscure the fact that the epicondyle is missing from its usual situation. Where it still remains in position abnormal mobility can be detected. With the fragment displaced into the joint there is a gross effusion of blood into the joint and restriction of movement, though the latter may not be as great as might be expected. The X-ray in such a case shows a fragment

2. Slight displacement. Reduction by manipulation and posterior gutter splint.

3. Gross displacement. Reduction by manipulation, and retention by ·

(a) Pin through the olecranon and traction with pressure on the epicondyles.

(b) If this fails, open operation and fixation (Fig. 306).

Accurate reduction is essential if the elbow is to function normally, and time should not be wasted between efforts to reduce the bone as callus is thrown out very early, particularly in children. The method of operative fixation in children is the same as adopted for fractures of the lateral condyle, but in adults a bone peg or screw may have to be employed.

Fractures of the medial epicondyle, and epiphyseal separation. The medial epicondyle being more prominent is more easily damaged than the lateral, but the mechanism is much the same. Abduction strain plays the part of adduction strain, and up to the age of sixteen the lesion may take the form of an epiphyseal separation. The most important mechanism, however, is that associated with a lateral dislocation of the elbow. When the elbow is seen dislocated the lesion is usually recognised, but in many cases there is a spontaneous



Fig. 307. Heterotopic ossification in the region of both epicondyles One fragment on the medial side is an old displaced medial epicondyle. The lateral fragment is an ossification in the radial collateral ligament.



Fig 308 Dislocation of the elbow with accompanying fracture of the medial epicondy showing it displaced in front of tl trochlea (see p. 661).

reduction of the elbow after the accident and the small fragment of the medial epicondyle is caught between the sigmoid notch of the ulna and the trochlea where it may be easily overlooked with grave consequences later (see p. 661 and Fig. [illegible])

DIAGNOSIS. The symptoms are comparable to those of the lateral epicondylar lesion. The flexor group of muscles may be weakened with inability to fully flex the fingers. Characteristic



FIG. 309. Fracture of the medial epicondyle with displacement of the epicondyle into the joint. Lateral view.



FIG. 310. Fracture of the medial condyle with displacement into the joint. Antero-posterior view, showing the epicondyle lying between the trochlea surface of the humerus and the sigmoid notch of the ulna. (Same case as Fig. 309.)

bruising extending down the flexor pronator group of muscles may be seen. The ulnar nerve is damaged to a variable degree in most cases, and in the case where the fragment has been displaced into the joint there is always a temporary complete lesion. In these cases hæmorrhage may obscure the fact that the epicondyle is missing from its usual situation. Where it still remains in position abnormal mobility can be detected. With the fragment displaced into the joint there is a gross effusion of blood into the joint and restriction of movement, though the latter may not be as great as might be expected. The X-ray in such a case shows a fragment

with a well-defined rounded border lying in the sigmoid notch, and usually best seen in the lateral film. Though the absent epicondyle is obvious it has been frequently overlooked and the A.P. film regarded as normal. This is a serious error.

Treatment. If there is no displacement, the flexor group is relaxed by a low cuff and collar. This is maintained for two to three weeks, and then a sling is substituted for it, and movements inside the sling commenced. At the end of a further week the sling is discarded.

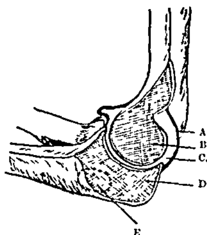


FIG. 311. Diagrammatic section of the lower end of the humerus showing the correct site for insertion of a Kirschner wire into the ulna, and its relation to the elbow. A. Posterior capsule of the elbow. B Section of the trochlea. C. The joint space. D Section of the sigmoid notch of the ulna. E. Area of the ulna through which the Kirschner wire is best inserted.

When there is moderate displacement, but the fragment is not in the joint, it can usually be neglected. Any grosser displacement is uncommon and requires pegging or suture.

If the condyle is in the joint operation is essential. A vertical incision is made over the condyle and the common flexor origin will be found to lead down to the fragment which lies in the joint. It is removed and the flexors and fragment stitched back in position. Most surgeons take the opportunity to transplant the damaged ulnar nerve anteriorly at the same time. The after-treatment is similar, except that immobilisation is maintained for three to four weeks before movements are allowed. In young people satisfactory union with no disability follows. In older patients there is likely to be some difficulty in regaining full extension.

In cases with little or moderate displacement the prognosis is always good.

Complicated or compound injuries to the elbow. These are treated on the same general lines as compound fractures elsewhere. To reduce swelling rapidly no position is so good as Zeno's position. For complete immobilisation in a compound fracture a cast is applied from the axilla to the heads of the metacarpals (Fig. 105). This may be put in Zeno's position by a strapping extension to the arm portion of the plaster, and a sling under the forearm. If a Kirschner wire has been used in the reduction its retention in *the olecranon* makes suspension so much the easier. If the swelling does not warrant elevation of the arm, it is wise to keep the patient in bed for a few days to reduce the swelling and œdema around the joint.

Complications of fractures in the elbow region. IMMEDIATE (See Chapters V and VI for complications in general.)

1. *Dislocation of the elbow.* The relationship of this to various fractures of the elbow has been discussed, and it indicates more serious damage to the joint, longer immobilisation, and a worse prognosis (see also p. 658).

2. *Dislocation of the head of the radius* from the radio humeral and radio-ulnar joint. (Mentioned so that it will not be overlooked.)

3. *Injuries to the main blood vessels.* If ruptured the vessel requires urgent treatment, as do all ruptured vessels. It is particularly important that the development of a tense hæmatoma in the cubital fossa be avoided. (See Volkmann's contracture and p. 56.)

4. *Injuries to the nerves.* Radial, ulnar, and median. This must be examined for and treated as outlined previously.

DELAYED. 1. *Myositis fibrosa.* (Volkmann's ischæmic contracture.) See earlier chapters for pathology and treatment.

2. *Myositis ossificans.* Occurs in the brachialis as a rule. It is increased by early passive and active movements (see earlier chapters).

3. *Excessive callus formation.* This may occur in all fractures in this region, with the exception of epiphyseal lesions. It is stimulated by early movements and is another reason why these should be avoided. Immobilisation results in its reduction in size in the early stages.

4. *Ossifying hæmatoma.* Related to excessive callus formation (see earlier chapters).

LATE. 1. *Mal-union.* Due to neglect, or to unavoidable causes. The most common disabilities met with are: (1) Posterior displacement of the lower fragment of the humerus in supra-condylar fractures with a consequent loss of flexion. This is cured by the growth of the bone in children. In adults an oblique osteotomy, with traction, may improve the position, but it is seldom necessary and is not a reliable cure. (2) Upward displacement of either condyle. This may lead to an adduction or abduction deformity at the elbow. In early cases it may be improved by osteotomy and fixing the arm in a corrected position. (3) Irregularity of epiphyseal growth. This leads to the deformity outlined above. Operative interference in these cases is inadvisable.

2. *Late ulnar neuritis.* This arises years later from the continued friction of the ulnar nerve in the ulnar nerve groove. It may be due to stretching of the nerve in an abduction deformity in which the carrying angle is *increased*, or due to pinching in an adduction deformity, in which the olecranon approaches the medial condyle,

or due to excessive callus around the medial epicondyle. Anterior transplantation of the nerve effects a cure. It is most commonly associated with mal-union of fractures of the lateral condyle.

3. *Traumatic arthritis.* This is essentially similar to the same condition in joints elsewhere. While the absence of weight-bearing relieves the joint of some strain, its peculiar construction and combined activities render any small alteration of alignment of bony surfaces a continued source of strain. Degeneration occurs with resultant pain, limitation of movement, presence of loose bodies, and occasional locking, while weakness of the grip and pain in the forearm is commonly complained of. The general aspects of treatment have been discussed before.

FURTHER READING

Upper End of the Humerus

WATSON JONES. "Fractures in the Region of the Shoulder Joint," *Proc. Roy. Soc. Med.*, 1936, 29, 1058.

GORDON. "Fractures of the Upper End of the Humerus," *Am. J. Surg.*, 1937, 38, 495.

FUNSTEN, R. V. "Fractures and Dislocations around the Shoulder," *J. Bone and Joint Surg.*, 1936, 18, 191.

FRANKAU, C. "Reduction of Fractures of the Surgical Neck of the Humerus," *Lancet*, 1933, *ii*, 755.

FAIRBANK, T. J. "Fracture-Subluxations of the Shoulder," *J. Bone and Joint Surg.*, 1948, 30B, 454–460.

MCLOUGHLIN, H. L., and ASHERMAN, E. G. "Lesions of the Musculo-tendinous Cuff of the Shoulder," *J. Bone and Joint Surg.*, 1951, 33A, 76.

DEPALMA, A. F. "Surgery of the Shoulder." Lippincott, Philadelphia, 1950.

WHISTON, T B. "Fractures of the Surgical Neck of the Humerus," *J. Bone and Joint Surg.*, 1954, 36B, 423.

Lower End of the Humerus

ARTHUR, A "Intra-articular Displacement of the Internal Epicondyle following Dislocation," *J. Bone and Joint Surg.*, 1938, 20, 161.

FAIRBANK and BUXTON. "The Displacement of the Internal Epicondyle into the Elbow Joint," *Lancet*, 1934, *ii*, 218.

BUXTON. "Ossification in the Ligaments of the Elbow Joint," *J. Bone and Joint Surg*, 1938, 20, 709.

COHN, I. "Observations based on the Study of Injuries to the Elbow," *Arch Surg.*, 1921, 3, 357.

SCRIS, I. E. "Supracondylar Fracture of the Humerus." Analysis of 330 cases. *Surg. Gynæ. Obst.*, 1939, 68, 201. (Analyses the displacement. None, 22 per cent.; backward, 74 per cent.; forward, 4 per cent.)

JONES, ROBERT. "Remarks on Injuries about the Elbow in Children," *Brit. Med. J*, 1932, 1, 739 (Good summary and general criticism.)

WEST, E. F. "Fractures in the Region of the Elbow," *Med. J. Australia*, 1937, 1, 773. (With further references.)

ROBERTS. "Displacement of the Internal Epicondyle into the Elbow Joint. Four Cases Treated by Manipulation," *Lancet*, 1934, *ii*, 78.

EASTWOOD. "The T-shaped Fracture of the Lower End of the Humerus," *J. Bone and Joint Surg.*, 1937, 19, 3 and 64.

WILSON. "Fracture of the Lateral Condyle of the Humerus in Childhood," *J. Bone and Joint Surg.*, 1936, **18**, 312. (With full bibliography.)
McDONNELL, D. P. M., and WILSON, J. C. "Fractures of the Lower End of the Humerus in Children," *J. Bone and Joint Surg.*, 1948, **30A**, 347.
HOYER, A. "Treatment of Supracondylar Fractures of the Humerus by Skeletal Traction in an Abduction Splint," *J. Bone and Joint Surg.*, 1952, **34A**, 623.
EVANS, E. M. "Supracondylar Y Fractures of the Humerus," *J. Bone and Joint Surg.*, 1953, **35B**, 381.
SMITH, F. M. "Surgery of the Elbow," 1954. Charles C. Thomas, Oxford, Blackwell.

CHAPTER XXII

FRACTURES OF THE RADIUS

Surgical anatomy. *The head of the radius lies comparatively superficially* below the lateral epicondyle, and above and behind the outstanding belly of the brachio-radialis, where it can be readily palpated and rotational movements imparted to it by twisting the wrist can be appreciated. The head of the radius plays a part in two joints, the radio-ulnar, and the radio-humeral. One fifth of its circumference only is in contact with the lesser notch of the ulna, but a segment of 160° comes in contact with it on pronation and supination. It is plain that fractures involving this 160° segment will affect movements more than fractures in that part only in contact with the annular ligament.

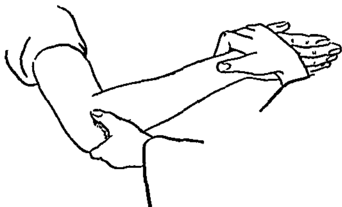


FIG. 312 The correct method of examining the head of the radius, for loss of rotation, or eccentric movement.

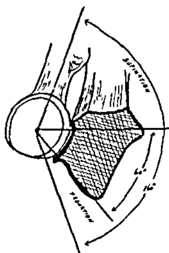


FIG. 313. Diagrammatic transverse section of the upper end of the ulna at the level of the head of the radius, to show the 60 degrees of circumference of head normally in contact with the lesser sigmoid notch, and the range of movement of pronation and supination on either side of it.

The shaft. The muscle balance is situated around the pronator teres insertion, which is into the highest part of the curve of the bone. Displacement in fractures of the shaft varies in relationship to this point.

1. *Above P. teres. Upper fragment. Flexed* and supinated by biceps, and supinated by supinator brevis.

Lower fragment. Pronated by pronator teres, and quadratus, and adducted by pronator quadratus.

2. Below P teres. Upper fragment. Flexed by biceps. Drawn medially but remains midway between pronation and supination.

Lower fragment. Drawn medially by pronator quadratus and insertion of brachio-radialis, and pronated.

The close relation of the abductor pollicis longus, and the extensor pollicis brevis to the bone here is to be noted, but they are at too great a mechanical disadvantage to produce displacement, though they may be caught between the bone ends.

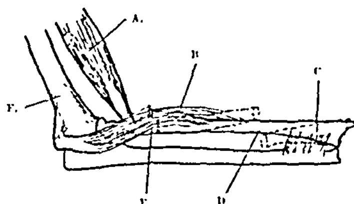


FIG. [illegible] [illegible] to show the influence of [illegible] the shaft of the radius. [illegible] quadratus. D. Fracture [illegible] [illegible]ove the origin of P. teres. F. Humerus.

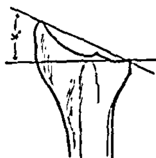


FIG. 315. Antero-posterior view of the lower end of the radius to show the angle of approximately 30 degrees made by the articular surface with the transverse.

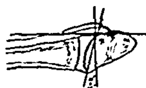


FIG. 316. Lateral view of the lower end of the radius to show the manner in which the articular surface looks downward and forward, at an angle of 10 to 15 degrees with the vertical.

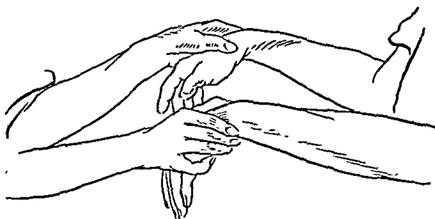


FIG. 317. Comparison of the relative levels of the radial and ulnar styloid processes of both wrists.

Lower end. The bony architecture of the bone here is *important*, for it is at the junction of the thick layer of compact bone of the shaft, with the thinner lamella clothing the cancellous bone of the distal end, *that the bone gives* in many fractures. The transition is very rapid, and the area is at a consequent mechanical disadvantage. The *upper margin* of the articular

surface overhangs the lower, so that the joint surface looks forwards and down at an angle of 10° to 15°, with the A.P. plane. The articular surface also makes an angle of 25° to 35°, with the transverse at the lower end of the bone, and these angles are important in the transmission of force along the bone, and so determine the lines of fracture. The styloid process lies ½ inch distal to the styloid process of the ulna.

Ossification. Radius and ulna.

Primary centres for the shafts appear at seventh week.

Secondary centres. (Rarely additional centres for the tip of the olecranon and radial styloid process.)

Distal	R.	Appears second year.	Unite with shaft eighteen to twenty-one. Ulna joining first.
	U.	Appears fourth year.	
Proximal	R.	Appears fifth year.	Unite with shaft seventeen to twenty. Ulna joining first.
	U.	Appears tenth year.	

FRACTURES OF THE HEAD OF THE RADIUS

These may be due to :—

Direct violence : Comminuted fractures. Fractures of neck.

Indirect violence : Fissure fractures, impacted and infraction fractures.

Other injuries commonly associated with fracture of the head of the radius may be :—

1. Dislocations of the elbow.
2. Fractures of the shaft of the ulna.
3 Dislocations of the head of the radius alone.
4. Fracture of the lateral condyle.
5. Chip off anterior surface of the capitellum. (This will not show in the X-ray if it is entirely cartilaginous.)
6. Rupture of ulnar collateral ligament of the elbow.



FIG 318. Chip fracture of the head of the radius. Compare Fig. 322.



FIG 319. Fissure fracture of the head of the radius. Compare Fig. 326.



FIG. 320. Fracture of the neck of the radius with displacement of the head.

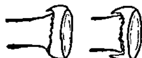


FIG. 321. Varieties of infraction fracture of the head of the radius

Types of fracture. 1. *Chip.* This is due to two radial fissures meeting and leaving a small fragment free.

2. *Fissure.* This may be complete, which virtually produces a large chip fracture or an incomplete split.

It is the commonest lesion of the head of the radius, and due to either heavy impaction against the capitellum, or forced abduction of the forearm at the elbow. Injuries to the medial side of the joint should therefore be sought for in association with

the fracture. The stretching is rarely sufficient to produce an ulnar nerve paralysis, but if it ruptures the ulnar collateral ligament may do so.

3. *Impacted fractures.* Usually just at the junction of the head and neck, where the compact bone is thin. May be difficult to detect, or there may be gross displacement of the head.

4. *Comminuted fractures* with gross damage and distortion.

5. *Epiphyseal separations.*

Diagnosis. Usually a characteristic story of a fall on the extended arm is given, followed by pain in the elbow and loss of the movements of pronation and supination. The joint is usually filled by an effusion which limits flexion and extension if it is not already limited by other damage, but it is interesting to note that in the absence of damage to any other part than the head of the radius, pronation and supination may be complete, and full extension impossible, and this may be the only sign present.



Fig. 322. Chip fracture of the head of the radius.

Examination may show local bruising. Pain is usually well localised. It is tested for with the thumb at the same time as *rotational movements of the head are tested for.* This test may elicit crepitus. Rarely in fractures of the neck the head may not rotate, or more commonly an excentric movement of the head is felt below the thumb (Fig. 312).

Accurate diagnosis demands an X-ray, as the following conditions may be associated with, or mistaken for, fracture.

1. Fracture of the lateral condyle or epicondyle.
2. Rupture of some fibres of the extensor group of muscles.
3. Hæmorrhage into the joint.
4. Dislocation of the head of the radius, especially if spontaneously reduced.
5. Pulled elbow, in which the synovial reflection around the head is pinched.
6. Osteo-arthritis of the joint.



Fig. 323. Comminuted fracture of the head of the radius. Compare Fig. 328.



Fig. 324. Displacement of the epiphysis of the head of the radius. Compare Fig. 331.

The following are some helpful points in the consideration of such cases.

Effusion of blood into the joint may be almost the only sign of fracture of the head of the radius.

The patient may neglect the original injury and come up because of loss of extension of the elbow.

In muscular rupture the strain is an extension strain and not compression. The hæmorrhage in this case tends to pass down the muscle group, and gives rise to characteristic bruising later.

Treatment. This demands careful consideration because of the two joint surfaces involved, and the fact that excision to attain its greatest success must be done early before the mal-position of the head has produced a traumatic arthritis, *i.e.*, within two or three weeks.

1. *Chip fractures.* If in good position, immobilise with a cuff and collar for three weeks and then commence active movements. If the chip is displaced and free it must be removed.

2. *Fissure fractures.* These can frequently be treated with a cuff and collar, as the fragment is in good position. With such fractures damage to the capitellum must be looked for which may result in more stiffness than may be expected. It is in fissure fractures, particularly the fissure most commonly met with, which separates almost the lateral half of the head, that the fragment is displaced downwards to some extent. This displacement can be corrected by placing the arm in full extension and adducting

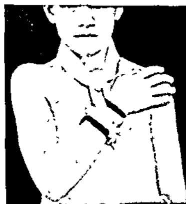


Fig. 325 Comfortable cuff and collar sling made with a padded triangular bandage tied over felt at the wrist.



Fig. 326 Fissure fracture of the head of the radius, with distal displacement of the fragment.

the wrist strongly. The annular ligament being intact then pulls the fragment up into position, and if the arm is put up in extension maintains it there. Extension being an awkward position for the patient, the arm is flexed as soon as the fragment has become attached, *i.e.*, in ten to fourteen days. The arm is then carried in a sling for a further fourteen days, movements being attempted during the last week. After *this full movement of the arm is* permitted.



Fig. 327. Same case as Fig. 326 after treatment, showing the restoration of the position of the fragment by treating the elbow *in extension*.



Fig. 328. Comminuted fracture of the head *of the radius*. X-ray showing forward dislocation of the head of the radius, and how the acute flexion of the elbow has produced the deformity. Treat*ment of the elbow in flexion* would tend to maintain this.

3. *Impaction fractures.* If the head is in good position leave it, if poor, operate. In the young, replace, in the old, remove.

4. *Comminuted fractures.* These can only be treated satisfactorily by removal of the whole head.

5. *Separated epiphysis.* Replace by manipulation or open operation. Never remove owing to the probability of interference with growth.

It is not justifiable to temporise and see how the joint progresses. If it becomes stiff permanent damage is done which cannot be undone by late excision of the head of the radius.

Operation. Carried out as a rule after the acute bruising has subsided, *i.e.*, in three to ten days. A tourniquet is used. The incision is two inches long in the line of the bone over the head of the radius The brachio-radialis is separated from the extensor

carpi radialis, and the joint capsule exposed. By cutting vertically through the radial collateral and annular ligaments the bone is exposed. The head is treated as necessary, and if removed



FIG. 329 Excision of the head of the radius after a comminuted fracture—satisfactory rounding of cut end of radius and absence of new bone formation. Note ossification in the ulnar collateral ligament, indicating that this was damaged at the same time as the fracture of the radius, by abduction violence.

entirely the neck is nibbled away to a rounded stump. No periosteum is separated and no tags left if possible. The wound is closed with one or two sutures in the capsule and in the skin, and no



FIG 330 Lateral view of the same case.

drainage A firm pressure bandage is applied. After this the Esmarch bandage or tourniquet is released. The elbow is then immobilised in a dorsal gutter splint at right angles for two weeks and then active movements are begun.

PROGNOSIS. This is good in all the minor fractures, and fairly good if the above lines of treatment are carried out. Where there is limitation of movement after an old fracture the result of operation is a little uncertain, but in a bad case an improvement is likely. If there is a bad traumatic arthritis present the results are bad, and much pain may demand an arthrodesis. The chief permanent disability likely to follow the injury is not loss of pronation and supination, but loss of complete extension. Major injuries may result in much permanent stiffness and this is only avoided by early operation. The results of complete excision of the head of the radius are, however, not so satisfactory that it should be done without suitable indications.



FIG. 331. Separation of the epiphysis of the head of the radius.



FIG. 332. Same case as Fig. 331 after operative restoration of the position of the epiphysis. Lateral view.

Complications. 1. *Arthritis.* Usually traumatic and secondary to an associated dislocation. Avoided by early reduction, removal of grossly displaced fragments and the avoidance of force later in dealing with limited mobility. Active movements by the patient only should be used to restore mobility. Once established, the possibility of improvement by excision of the head must be considered. The usual physio-therapeutic treatment may make the life of the patient more comfortable and prevent the condition getting worse.

2. *Loss of pronation and supination.* Do not forget to examine the lower radio-ulnar joint as well. Usually due to leaving displaced fragments *in situ* or excessive callus. Excision of the head must be considered.

3. *Loss of flexion and extension at the elbow.* Often a small

amount of extension is lost, but as the patient never uses the elbow fully extended it is of little moment.

4. *Paralysis of the posterior interrosseous nerve.* May be due to injury at the time of the accident or to a later developing traumatic neuritis from the friction of a deformed radial head. The features are those of a radial palsy, without the loss of skin sensation. Immediate lesions of the nerve are very rare, and the associated injury would inevitably demand operation. In late lesions the head is excised.

5. *Osteochondritis dessicans.* Damage to the capitellar surface of the humerus, with or without fracture of the head of the radius, may result in the later separation of a flake of bone, with all the features of a loose body in the elbow. The sclerosis below the site of separation suggests its similarity to the lesion occurring in the knee.

FRACTURES OF THE SHAFT OF THE RADIUS

Fractures of the shaft of the radius alone is rare, as :—

1. The shaft is dense compact bone, and the cancellous bone at either end gives first.
2. A mobile joint at either end tends to dissipate force.
3. In direct injuries, such as warding off a blow, the ulna is more superficial and thus more frequently injured.

Fractures in adults, when they do occur, are most commonly due to direct violence, and so tend to be transverse. They are more common in children and then are frequently greenstick, and are often associated with fractures of the ulna. In the lower end there is a particular tendency to infraction fractures, which occur a little above the site for Colles's fractures.

DIAGNOSIS. The upper third of the radius is buried in muscle and so less likely to be injured, but correspondingly more difficult to examine. Deformity in the lower subcutaneous portion is often obvious. There is a loss of active supination in all fractures. Rotation of the head of the radius transmitted from the wrist is not evidence against fracture, as it may be impacted or greenstick, but non-rotation of the head is proof of fracture. An X-ray is often necessary in children, whose only complaint may be a refusal to use the arm, and a little local swelling.

TREATMENT (see *Displacement*, p. 98) :

Fractures above pronator teres. } {With no displacement.
Fractures below pronator teres. } {With displacement.

1. Fractures above the pronator with no displacement. Immobilise with the arm in full supination and the elbow at 90° for four weeks.

2. With displacement. This can only be angulation or shortening, and these must be corrected by manipulation. Traction to

correct the shortening must be firm and with the wrist in ulnar deviation, to overcome the splinting of the ulna, and finger pressure is made to correct the angulation. The arm is then immobilised in the supinated position with the elbow at about 60° by a posterior gutter splint. Union is slow, and may take four to six weeks.

3. Fractures below the pronator teres, with no displacement. The arm is put in a plaster from the mid-humerus to the metacarpal heads to prevent rotation, care being taken that the bones are not pushed together, and with the elbow at 90°, and the forearm in the mid-prone position.

4. With displacement. Reduction by manipulation, followed by a plaster, as before. Union occurs in four to six weeks in an adult, three weeks in the child.

If reduction by manipulation does not produce a good reduction, perfect reduction should be achieved by open operation. The ends may interlock sufficiently well not to need any fixation, but it is safer to insert a single screw. As less desirable alternatives, the methods discussed under fractures of both bones of the forearm (p. 397) may be used. Perfect reduction of the radius is important, but not quite so important as perfect reduction of the ulna.

Greenstick fractures should have any angulation corrected by manipulation, a proceeding which often turns them into complete fractures. They are then immobilised in a short forearm plaster, for two or three weeks. In children with complete fractures in the distal fourth of the bone it is unnecessary to immobilise the elbow, the forearm being carried in a sling for the first two weeks and then exercised as in a Colles's fracture. Infraction fractures require a supporting plaster up to the elbow for two to three weeks, and can use their hands freely.

Fractures of the lower fourth of the shaft of the radius. These fractures fall into two groups .

1. Those in which the lower radio-ulna joint is intact ;
2. Those in which there is a dislocation of the lower radio-ulna joint (Fig. 335)

They occur from backfire injuries or from direct violence applied to the radius. The dislocation of the ulna is forwards in nearly all cases. This displacement is readily overlooked if the radiographs are not true lateral views of the wrist, and as failure to reduce the dislocation produces considerable disability its importance needs to be emphasised The persistence of some pain at the lower radio-ulnar joint and some loss of supination is not uncommon after this injury. Accurate reduction of the radius is important in all cases and must be obtained by one of the following methods. Once reduced there is often a tendency to redisplace, particularly in those

amount of extension is lost, but as the patient never uses the elbow fully extended it is of little moment.

4. *Paralysis of the posterior interrosseous nerve.* May be due to injury at the time of the accident or to a later developing traumatic neuritis from the friction of a deformed radial head. The features are those of a radial palsy, without the loss of skin sensation. Immediate lesions of the nerve are very rare, and the associated injury would inevitably demand operation. In late lesions the head is excised.

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DIAGNOSIS The upper third of the radius is buried in muscle and so less likely to be injured, but correspondingly more difficult to examine. Deformity in the lower subcutaneous portion is often obvious. There is a loss of active supination in all fractures. Rotation of the head of the radius transmitted from the wrist is not evidence against fracture, as it may be impacted or greenstick, but non-rotation of the head is proof of fracture. An X-ray is often necessary in children, whose only complaint may be a refusal to use the arm, and a little local swelling.

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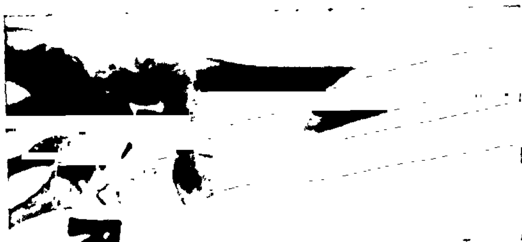


FIG. 335. Oblique fracture of the lower end of the radius, accompanied by dislocation of the lower radio-ulnar joint.

with a Kirschner wire. This wire may run transversely across the radius and ulna, or it may be more easily and equally satisfactorily introduced from front to back. The wire is incorporated in the plaster.

3. Open operative reduction and fixation. This is most satis-

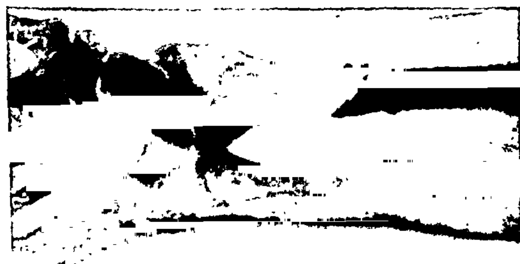


FIG 336. Fixation of the fracture by a single screw.

factorily carried out by a small plate. Less convenient are a single oblique screw or a graft.

It is essential to fix the elbow as well as the wrist in immobilising these fractures. Union is satisfactory in four to six weeks. If there is any doubt a short forearm plaster is applied for a further fortnight. This unstable lesion is the homologue of the Monteggia fracture dislocation in the upper third of the forearm. Both may reduce easily, but are subject to later displacement of the fracture, usually



FIG. 333. Fracture of the lower end of the radius, with dislocation of the lower radio-ulnar joint.



FIG 334. Fracture of the lower end of the radius together with complete dislocation of the lower radio-ulnar joint

cases associated with dislocation This may be due to the pull of *the pronator quadratus*, but is *more commonly* due to *imperfect* reduction, a rotational deformity being apt to remain unrecognised. Methods of reduction and retention available are :—

1. Manipulation and plaster. Suitable in cases which interlock readily and in greenstick fractures of the type shown in Fig. 333.

2. Manipulative reduction and transfixion of the lower fragment

upper end of the humerus occurs. Indeed they may occur together, and cases have been seen in which the concentration of attention on the wrist lesion has caused the humeral fracture to be overlooked.

The name Colles's is applied to a transverse fracture of the lower end of the radius which occurs just distal to the point where the compact bone of the shaft thins to become the covering of the



FIG. 337. Characteristic "Dinner Fork" deformity of a Colles's fracture.

cancellous bone of the lower end. It is thus a fracture through cancellous bone. With this is frequently associated a fracture of the ulnar styloid process which may be broken transversely at its base, or merely have a chip pulled out from the tip. In a severe



FIG. 338. Colles's fracture with moderate displacement. Lateral view.

Colles's fracture where the ulna styloid is not fractured the ulnar collateral ligament is torn, but this is very uncommon as fracture usually occurs first

Clinically, Colles's fractures can be divided into mild and severe. In the mild cases the diagnosis rests between a Colles's and any other of the seven fractures named. In the severe case with marked displacement it rests between a Colles's, a separated epiphysis, and a fracture of both bones a little above the wrist. The clinical

angulation, with impaired function. Open operative fixation with the control provided by a plate or Kuntscher nail, is therefore recommended in all cases (see p. 401).

Traction on the thumb has been recommended for controlling these cases. It is to be avoided as it produces serious stiffness in the thumb.

FRACTURES OF THE LOWER END OF THE RADIUS

Types. 1. Colles's fracture, and reversed Colles's or Smith's fracture.
2. Marginal Fractures. Dorsal.
3. ,, ,, Volar.
4. ,, ,, Styloid.
5. *Longitudinal fissure fractures.*
6. Separation of the lower epiphysis.
7 Infraction fractures. (Greenstick, with little displacement.)

Colles's fractures. Mechanism. 1. **Direct violence.** Starting-handle injuries. There are two varieties of starting-handle *injuries :—*

(*a*) Backfire on the downward compression. This drives the handle into the palm and produces a Colles's fracture or fracture of the navicular.

(*b*) The backfire on the upward compression, in which the handle is torn out of the hand and swings around striking the back of the wrist. This usually produces a transverse fracture of the lower end of the radius above the level of the Colles's fracture and which may be associated with dislocation of the lower radio-ulnar joint (p. 401).

2. **Indirect violence.** Falls in which the hand is used to save the body. In falls with the hand palm down, the force on the thenar and hypothenar is transmitted up the bones of the forearm, and may be accompanied by acute dorsiflexion and a rotational strain, on the lower end of the radius, the fingers acting as part of a short lever. Falls with the hand doubled under in which the hand is hyperflexed should produce the characteristic Smith's fracture, but rarely do so, and they more commonly produce a Colles's fracture.

Incidence. The fracture is particularly common in middle-aged women, *when some general decalcification of bones*, accompanied by an increased deposit of fat, seems to occur after the menopause (see table in Chapter I). In such cases if the wrist does not give, and the force is sufficiently strong, an impacted fracture of the

to impaction, and must be distinguished from the soft crepitus of epiphyseal injuries. There is a loss of pronation and supination.

Associated injuries which must be watched for :—

1. Dislocation at the lower radio-ulnar joint.

2. Injury to the sensory branch of the radial nerve, with pain around the base of the thumb, often considered due to the plaster.

3. Fracture of the navicular. Rare.

4. Injury to elbow, humerus or clavicle.



Fig. 341. Comminuted Colles's fracture with marked displacement. Lateral view.

Comminution of the lower fragment is not uncommon in severe injuries, usually in the old, the crack running into the joint, and it is important as it makes retention less easy, producing an effusion into the joint and an irregular joint surface with consequent increased disability later. It is particularly in these comminuted fractures that a watch for a recurrence of the deformity in the plaster must be kept, and a control X-ray taken about the tenth day. If it shows a recurrence the fracture is re-reduced in exactly the same manner as before. In old people with a Colles's fracture of any degree of severity a large hæmatoma appears at the elbow, around the medial epicondyle.



Fig. 342. Same case as in previous figure. Antero-posterior view.

Treatment. For perfect function perfect reduction is essential. All Colles's fractures should be reduced if there is the slightest displacement, even if impacted. The essentials of a good reduction, only seen in the X-ray, are :—

features will be obvious from the description of the deformity which follows.

The distal fragment is displaced :—

1. As a whole dorsally.
2. As a whole upwards, *i.e.*, towards the elbow.
3. It is rotated on a transverse axis so that the upper margin



Fig. 339. Same case as previous figure. Antero-posterior view.

of the bone *is turned dorsally, and the lower articular surface tends* to look dorsally.

4. It is rotated on an A.P. axis so that the radial styloid is pushed upwards to the level of the ulnar styloid, and the articular surface of the radius is more at right angles to the shaft.

This produces the characteristic dinner-fork deformity. The fourth displacement allows the hand as a whole to move radially, and the ulnar styloid or its fractured base becomes prominent. The diagnosis is usually obvious, but in the less displaced fractures only an X-ray will distinguish it from the fractures previously mentioned. The displacements described above can be verified by palpation before swelling has occurred. The whole wrist from above appears broadened, and the fingers are flexed to relax the tendons over the volar aspect of the fracture. Crepitus is often absent due

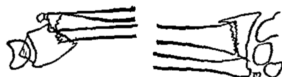


Fig. 340. Lateral and A.P. views of the radius showing the characteristic displacement of a Colles's fracture. (Compare Figs. 341, 342.)

REDUCTION. The patient is placed on a table, and the thumb and index, middle, and ring fingers are painted with mastisol, and a few turns of bandage placed around the three fingers and the thumb



FIG. 345. The stages in the reduction of a Colles's fracture. The introduction of the local anæsthetic.

separately, leaving the little finger free. A pad is then placed over the arm in front of the biceps, and a broad webbing loop slipped over the arm, which can be attached to a hook in the wall. The patient or the fracture site is then anæsthetised. Disimpaction and reduction is then brought about by firmly grasping the wrist and the hand, and strongly palmar flexing it at the wrist. With much the same grip and only shifting the two thumbs over the fracture site, dis-impaction can be readily tested by dorsiflexing the wrist. Reposition of the loose fragment is now brought about by traction on the fingers, the strap in the crook of the elbow providing counter-traction. The fingers are held in one hand and the thumb in the other and traction is applied mainly to the thumb which produces ulnar deviation and so corrects the radial displacement. Grasping only three fingers does not contract the metacarpal arch, as does grasping the whole four. Traction is applied with the arms straight, and the body leaning back, as with flexed



FIG. 346 The syringe is removed, allowing blood stained anæsthetic solution to trickle back along the needle, thus showing that the hæmatoma has been entered.

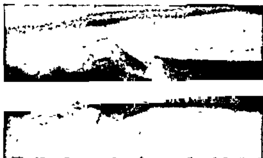


FIG. 343. Colles's fracture in Fig. 341 after reduction. The curve of the under surface of the radius is restored. The joint surface looks down and forward. It has been impossible to elevate a small depressed fragment which spoils the alignment of the dorsal surface, but this is of no moment.



FIG. 344. Antero-posterior view of the previous case showing the reduction of the ulnar styloid and the ulnar deviation of the hand.

1. The line of the dorsal surface of the radius is smooth and not stepped or angled (Fig. 343).

2. That the articular surface in a lateral view looks down and forwards at an angle of 10° to 15° (Fig. 343).

3. That the line of the articular surface in the A.P. view is at least at an angle of 25° with the transverse (Fig. 344).

4. That the ulnar styloid is in position, and the hand deviated ulnarwards (Fig. 344).

5. That the lower radio-ulnar joint surfaces are in normal relationship.

ANÆSTHESIA. Local anæsthetic is very suitable in recent cases. Any general anæsthetic may be used.

Technique of local anæsthesia. Using the apparatus and method set out previously, two skin blebs are first raised with fine hypodermic needles, one over the base of the ulnar styloid (unnecessary if the ulnar styloid is intact) and one over the lateral surface of the radius just below the line of fracture. A larger needle is now taken and 2½ c.c. of 2 per cent. novocaine is injected at the base of the fractured ulnar styloid. A fresh needle is taken and entered obliquely against the upper surface of the bone. By sliding it over this the fracture line can be readily felt and the hæmatoma entered. Fifteen cubic centimetres of 2 per cent. novocaine are injected here. In order to be certain that this is diffusing into the hæmatoma, after the first few cubic centimetres are injected the syringe is detached and blood-stained fluid should regurgitate back along the needle. If there is little displacement of the fragments it will be found necessary to pass the needle in front of the bone and inject some novocaine there, as otherwise it will not percolate through the impacted bone to this region.

This dorsal slab is now carefully smoothed on to the skin. The further wrapping to maintain this in place depends on whether swelling of the fracture site is to be anticipated. If the fracture is fresh and no swelling has taken place, a gauze bandage is wrapped around



Fig. 349. Testing for complete disimpaction by hyper-extension with the fingers on the fracture site.

the plaster slab. If swelling has occurred a plaster bandage may be used, care being taken in both cases that the portion crossing the palm is not too tight. The plaster is carefully moulded as it sets, so that there is a hollow under the lower surface of the radius, and a smooth fit around the base of the first metacarpal. This not only helps to turn the lower end of the radius in the correct direction, *i.e.*, looking



Fig. 350 Traction applied to the forearm. There is a counter traction band around the arm attached to a hook in the wall. The nurse pulls with straight arms, using the body weight, which is much less tiring.

elbows the traction is uneven and tiring to maintain. By traction the shortening is overcome, and the dorsal rotation, which was undone by the disimpaction, is also corrected. The shifting of the whole fragment dorsally is usually also undone, but it may be made certain by pressure with the thenars on either side of the fracture, with the fingers interlocked, when great force can be exerted. This manœuvre is very useful in comminuted fractures with much displacement, and by maintaining the traction, and combining a rocking movement with the pressure, the fragments can all be worked back into position. The arm is now held in flexion at the elbow, and midway between pronation and supination. *The wrist is in the neutral position*, and this is the ideal position for plastering. Very rarely is it necessary to palmar-flex the wrist to maintain the fragments in place, and if this is done it should only be left so for ten days and then replastered in the more usual position.

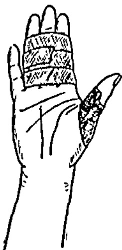


FIG. 347. The correct way to bandage the fingers for applying traction in the reduction of a Colles's fracture. The fingers are first painted with mastisol.

RETENTION. A plaster slab about six layers deep is now placed on the dorsum of the forearm and trimmed so that it extends from the heads of the metacarpals to just distal to the elbow crease, and so allows full flexion of the elbow. It must be sufficiently wide to wrap around the metacarpals on either side, a firm grip around the base of the first metacarpal being particularly important. A small cut is made beside the second metacarpal to allow the plaster to be folded back to the level of the head of the thumb metacarpal and give an edge for the binding across the palm.



FIG. 348. Disimpaction of the fracture by firm flexion of the wrist.

point is frequently overlooked in the region of the index finger which comes out of the plaster much stiffer at the metacarpal joint than the other fingers.

5. The plaster must extend to the end of the first metacarpal or pressure sores on the thumb will occur.

In comminuted or badly displaced fractures, and particularly in incompletely reduced fractures, a tendency for the deformity to



FIG. 353. With the arm still under traction, which is not relaxed till the plaster has set, the short forearm plaster is applied. In the figure the corner which is cut off to allow full flexion of the elbow is being removed.

recur in the plaster will be found. It seems to occur about the seventh to tenth day and should be checked by a routine X-ray on the tenth day. It is possibly due to a subsidence of the swelling allowing redisplacement in the cast. If it occurs the wrist is set again as if the fracture were a recent one.

COMPLAINTS WITH REGARD TO THE PLASTER.

1. Pain over the thumb. May be due to injury to the sensory branch of the radial nerve, and not due to pressure. Usually the plaster has to be removed and reapplied.

2. Swelling of the fingers. Is not uncommon for the first forty-eight hours, but goes away with exercise of the fingers. The precautions with regard to fresh fractures should be noticed. If swelling occurs the plaster must be split and the arm raised above the head and exercises encouraged. Recently we have developed the habit of cutting down the gauze bandage from the base of the fingers to two-thirds of the way down the forearm, half an hour after the plaster has set, and then lightly rebandaging. By this means the firm bandage necessary to hold the plaster in position can be applied, and all possi-

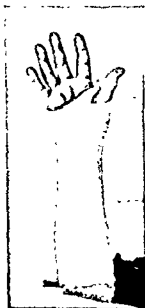


FIG. 354. The complete plaster. From in front.

downwards, but very definitely helps in the retention, while the moulding around the metacarpals is the only way in which the resistance to shortening can be maintained. Traction is only relaxed when the plaster is set. If a plaster encircling bandage has been used the date of fracture, date of plastering, and approximate date of removal,



FIG 351. While the wrist is under traction manipulation of comminuted fragments into position may be done by pressure of the palms with the fingers locked, accompanied by a rocking motion of the forearms.

together with a diagram of the fracture, are written on the plaster *with an indelible pencil. This is only to facilitate treatment in a large* clinic. If a gauze bandage has been used, provided everything is satisfactory on the following day, it is then covered with a starch bandage, on which the same details can be written.

The important points about a plaster for a Colles's fracture are :

1. It extends from the elbow to the heads of the metacarpals, but allows full flexion of the elbow.

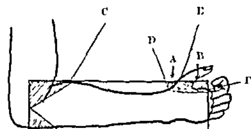


FIG 352. Trimming the plaster slab used in the retention of a Colles's fracture.

down to level of E for cutting flap A. [In applying a plaster for a fractured navicular in which the thumb is not fixed this portion of plaster is also removed]

2. It is sufficiently wide to surround the metacarpals on either side, for it is only the resistance offered by moulding it around the cone of the metacarpals which prevents the occurrence of shortening.

3. The metacarpal arch of the fingers must be flat to allow full finger movements.

4. The band crossing the palm which maintains the metacarpals against the dorsal slab, and which can be of wire, or of sticking-plaster, must not extend further than the level of the distal crease of the palm on the ulnar side and the middle crease on the radial side, so that full flexion of the fingers is possible. This

not amount to a disability. More of a problem is the persistence of pain, and the development of a traumatic arthritis in older patients. In severe comminuted fractures this is always to be feared.

Re-education. This is one of the most important parts of treatment, if not the most important part, and must be combined with the supervision of the plaster. The maintenance of adequate joint and muscle function is only possible by free exercises of the unfixed joints, and it is the ability to leave so many joints free, and yet maintain adequate fixation, that makes plaster the only satisfactory means of retention in this fracture. The patient is seen on the second day, and if the plaster is satisfactory, is instructed to do without the sling and use the fingers as much as possible in the ordinary way. To make certain that the arm is adequately exercised he is sent to the massage department for exercises, as follow:

1. Extension of the fingers, deliberate and strong.
2. Spreading of the fingers.
3. Flexion of the fingers.
4. Extension and flexion of the thumb.
5. Extension and flexion of the elbow.
6. Hand behind head and behind back.
7. Pronation and supination of the hand with the elbow steadied on the thigh if patient is seated, or held in against side if standing, and in the elbow grasp position if possible.

Complications. 1. REDISPLACEMENT. Occurs: (*a*) About seventh to tenth day, re-reduce and plaster.

(*b*) If plaster is removed too soon in old people, and in badly comminuted fractures. Depending on how serious this is and on the time since the fracture, one must decide between leaving it or re-reducing it.

2. PAIN OVER THE ULNAR STYLOID. Common complaint due to non-union of the styloid or the torn ulnar collateral ligament. Demands more careful ulnar adduction in the plaster to avoid it. If it occurs after the plaster is removed it will pass off in time in most cases, but in a very few the detached fragment has to be removed. Novocaine infiltration should be tried.

3. PAIN OVER THE SENSORY BRANCH OF THE RADIAL NERVE. Usually settles in time.

4 LOSS OF PRONATION AND SUPINATION TO SOME DEGREE. Due to arthritis of the lower radio-ulnar joint, and usually improves with time. It occurs in badly reduced and grossly comminuted fractures. In patients in the twenties and thirties, if very severe may require excision of the lower end of the ulna.

5. LATE RUPTURE OF THE EXTENSOR POLLICUS LONGUS TENDON. Very rare, but an interesting complication, and difficult to treat, as the fragment of bone causing the fraying must be removed and the frayed tendon may be in no condition for suture. A free tendon

bility of later constriction is removed by splitting the bandage, while the freeing of the venous return at the wrist improves the colour of the fingers.

3. Inability to move the fingers is commonly complained of even in normal plasters, and is due to pain, nervousness, and pressure. Some relief of pressure, *e.g.*, by a partial split down the forearm, and encouragement cures the condition. This is also a symptom of more serious pressure (see Chapter V), and this must not be overlooked.

Prognosis. Fractures can be classified as follows, and this serves as a guide to the prognosis, and also to the time of immobilisation necessary in each case. The fracture of the ulnar styloid can be neglected, except in so far as it indicates a more severe lesion.

Uncomminuted fractures. 1. With little displacement. (Mild Colles's.) (Plaster 2—3 weeks.)

2. With displacement and fracture of the ulnar styloid. (Severe Colles's.) (Plaster 3—4 weeks.)

Comminuted fractures. These almost always show gross displacement.

1. With the comminution not involving the joint surface. (Plaster 4—5 weeks.)

2. With the line of the comminuted fragments entering the joint. (Plaster 5—6 weeks.)

In this classification the fractures are arranged in the order of their seriousness. The last group of severely comminuted fractures involving the wrist joint may also involve the lower radio-ulnar joint with further disability.

The length of immobilisation increases with the severity of the lesion. In young people the uncomminuted and undisplaced fracture may be given a minimum period of two weeks in plaster. For each further degree of severity another week of immobility is insisted on, so that in the grossly comminuted fracture involving the joint five weeks rest may be needed. In older patients these times are each increased by a further week To obtain the total disability period, an equivalent period for rest and exercise must be added to that already spent in plaster.

Given uniform treatment the final result will be a reflection of the increasing severity of the lesion. The two important factors which will govern the prognosis more than any others are; accurate reduction and the presence of a fracture line running into the joint. Accurate reduction is essential for good function. The fracture entering the joint is bound to disturb the smoothness of the articulation, and such patients are much slower in gaining a wrist free from pain with reasonably full movements. In such cases complete restoration of movement seldom occurs, but the amount lost should

the angle of the joint. The other displacements are as in Colles's fracture. The radial styloid is elevated, and the general deformity has been called the "spade-handle deformity."

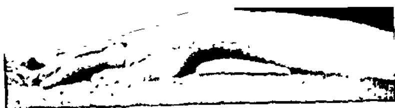


FIG. 357. The deformity in a reversed Colles's fracture. The same case as in Fig. 356.

TREATMENT. Follows similar principles to a Colles's fracture, the movements of reduction being reversed, and the wrist is put up in the same neutral position.

THE MARGINAL FRACTURES

1. Dorsal.
2. Volar.
3. Styloid.

The mechanism is much the same in dorsal and volar marginal fractures, and resembles that of a Colles's fracture, the force varying in direction, in the amount of leverage from the hand combined



FIG. 358. Dorsal and volar marginal fractures of the lower end of the radius.



FIG. 359. Styloid marginal fracture. Compare Fig. 363.

with the compression and in degree. The deeper overhanging posterior articular margin tends to receive more force. The injury is often regarded as minor, but is important owing to joint involvement and may be associated with a dislocation of the wrist in a palmar or dorsal direction.

SIGNS. Similar to those for a Colles's fracture, without much deformity, and from which it can only be distinguished by X-rays. The differential diagnosis rests between injury to the carpal bones, a severe sprain, separation of the epiphysis, and a mild

graft may be employed, or the distal end implanted into the abductor pollicus longus.

6. PERSISTENT PAIN IN THE WRIST. (*a*) Too early removal of the plaster. Immobilise for a further two weeks.

(*b*) Rheumatic flare-up in the injured joint. General physiotherapeutic treatment.

(*c*) Early traumatic arthritis. Usually associated with comminution or a bad reduction. These cases seen up to these months after the accident can be refractured and reset, but this is only advisable in the younger patient.

7. DEFORMITY. This usually takes the form of radial deviation, with a prominent ulnar styloid, and is the most common complaint in inadequately reduced or immobilised fractures, and can only be avoided by careful observation of the principles outlined. If very marked it may be corrected in the young by osteotomy of the radius and resetting. In the old it is best left alone.

Reversed Colles's or Smith's Fracture

Due most commonly to direct violence knocking the hand volarwards, but may be due to indirect violence in falls on the dorsum of the hand with the hand strongly flexed.



FIG. 355 Lateral and A P. views of a reversed Colles's fracture. (See Fig. 357.)

DEFORMITY. Not characteristic, and may be confused with volar dislocations of the wrist. The signs and symptoms are much the same as for a Colles's fracture, only the displacement is volarwards as a whole, and the rotation in the transverse axis increases



FIG. 356. Smith's fracture or the reversed Colles's fracture.

the angle of the joint. The other displacements are as in Colles's fracture. The radial styloid is elevated, and the general deformity has been called the "spade-handle deformity."

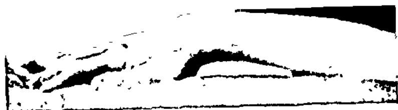


Fig. 357. The deformity in a reversed Colles's fracture. The same case as in Fig. 356

Treatment. Follows similar principles to a Colles's fracture, the movements of reduction being reversed, and the wrist is put up in the same neutral position.

THE MARGINAL FRACTURES

1. Dorsal.
2. Volar.
3. Styloid.

The mechanism is much the same in dorsal and volar marginal fractures, and resembles that of a Colles's fracture, the force varying in direction, in the amount of leverage from the hand combined

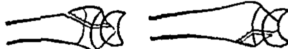


Fig. 358 Dorsal and volar marginal fractures of the lower end of the radius



Fig. 359. Styloid marginal fracture. Compare Fig. 363.

with the compression and in degree. The deeper overhanging posterior articular margin tends to receive more force. The injury is often regarded as minor, but is important owing to joint involvement and may be associated with a dislocation of the wrist in a palmar or dorsal direction.

Signs. Similar to those for a Colles's fracture, without much deformity, and from which it can only be distinguished by X-rays. The differential diagnosis rests between injury to the carpal bones, a severe sprain, separation of the epiphysis, and a mild



Fig. 360. Volar marginal fracture of the radius with anterior subluxation of the wrist.



Fig 361 Showing the effect of dorsiflexion in increasing the subluxation.



Fig. 362. Showing the reduction of the displacement by splinting the hand in the neutral (mid-) position.

Colles's fracture. The dislocation of the wrist as a whole must not be overlooked as it demands a much longer period of immobilisation than the fracture alone (*i.e.*, six to eight weeks).

REDUCTION. In each case the detached fragment is attached



FIG. 363 Marginal fracture of the radial styloid. The fracture line enters the joint just medial to the ridge between the navicular and lunate articular areas.

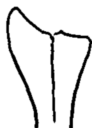


FIG. 364 Longitudinal fissure fracture of the radius. Compare Fig. 365.

to the carpus by its appropriate ligament, and it is through carpel manipulation that its position is influenced. In the radial styloid fracture, which usually runs straight out from immediately lateral to the articular ridge on the carpal articular surface of the radius to the lateral margin of the bone, it is seldom displaced, and can usually be plastered with no reduction. The volar and dorsal fractures may, however, be difficult to retain, on account of the associated dislocation. The tendency is to put the wrist into dorsiflexion in the volar fractures to draw the fragment down and into position. This, however, is an unstable position for the wrist, which partially dislocates, and the neutral position with some extension has to be adopted. Applied with the same technique as for a Colles's fracture, a plaster in the neutral position will hold either fracture in good position.

The re-education exercises are those of a Colles's fracture.

Fractures of the tip of the radial styloid with no displacement may be treated by strapping when they are



FIG. 365. Longitudinal fissure in the lower end of the radius.

small, but in the presence of pain it is better to put them in plaster for a fortnight, as, unless adequately treated, pain may persist for some time.

Longitudinal Fissure Fractures. Occur in softer bones as a rule from the same force which in hard bones produces the styloid marginal fracture. Reduction is not needed, and they require only a fortnight in plaster.

Radial Epiphysis

Separation of the radial epiphysis with or without that of the ulna occurs up to the sixteenth year. The displacement may be marked and resemble a Colles's fracture, with the exception that the crepitus is softer, as the fracture occurs on the metaphyseal side of the epiphysis, and so one side is cartilaginous. On the other hand it may be very little displaced and resemble a badly sprained wrist. In both these cases, if the tender spot is well localised it is found to be nearer the radial styloid than the tenderness of a Colles's fracture When the epiphysis is markedly displaced it always carries a chip of the dorsal margin of the metaphysis with it (Fig. 369). Separation of the ulnar



Fig. 366. Severe deformity accompanying separation of the radial epiphysis. The same case as shown in Fig. 367.



Fig 367. Posterior displacement of the radial epiphysis with separation of the ulnar styloid process. Antero-posterior view of case shown in Fig 368



Fig 368 Lateral view of the previous case.

epiphysis or fracture of the ulnar styloid (see Fig. 367) may be associated with the condition.

REDUCTION. This is usually easy, and the crenellated surface of the epiphysis, once back in position, tends to stay there. A dorsal plaster, as for a Colles's fracture, is applied. Union is satisfactory in three weeks in all cases. If the epiphysis is replaced interference with growth never occurs. It is very difficult to connect Madelung's deformity with mal-united fractures of this type, but it may develop after crushing injuries of the epiphysis which cause premature fusion (see Fig. 590).



FIG. 369. Posterior displacement of the lower epiphysis of the radius, showing the small fragment of the metaphysis carried away with the epiphysis (see Fig. 587).

Infraction fractures. These occur in the young and are really greenstick fractures with little displacement. As a result deformity is frequently hardly visible and barely palpable, and swelling and pain often the only symptoms complained of.

The X-ray is characteristic, showing a slight bulging of the compact bone between 1 and 2 inches behind the joint in the A.P. view, and some crumpling of the compact bone with deformity in the lateral view. All grades of this may be found, passing into the



FIG. 370. Greenstick (bamboo) fracture of the lower end of the radius. Antero-posterior view.

complete fracture of the lower fourth of the bone, described under fractures of the shaft.

TREATMENT. Where the displacement is small a supporting plaster for two weeks is sufficient, but where displacement has occurred it must be corrected by manipulation and a forearm



FIG. 371. Lateral view of the same case, showing crumpling of the posterior compact bone. More often the anterior side of the radius crumples.

plaster applied for three weeks. In children exercises are unnecessary.

FURTHER READING

Colles's Fracture

GURD, F. B. "The Colles-Pouteau Fracture of the Lower End of the Radius," *Am. J. Surg.*, 1937, 38, 526.

PLATT, H. "Colles's Fracture of the Radius," *Brit. Med. J.*, 1932, 2, 288. (With some historical details, and references.)

MOORE. "Spontaneous Rupture of the Extensor Pollicis Longus Tendon associated with Colles's Fracture," *Brit. J. Surg.*, 1936, 23, 729. (With further references.)

MCMASTERS, P. E. "Late Ruptures of the Extensor Pollicis Longus and Flexor Pollicis Longus Tendons following Colles's Fracture," *J. Bone and Joint Surg.*, 1932, 14, 93.

GARTLAND, J. J., and WERLEY, C. W. "Evaluation of Healed Colles Fractures," *J. Bone and Joint Surg.*, 1951, 33A, 895.

BACORN, R. W., and KURTZKE, J. F. "Colles Fracture," *J. Bone and Joint Surg.*, 1953, 35A, 643.

Head of the Radius

FLEMING, C. W. "Fractures of the Head of the Radius," *Proc. Roy. Soc. Med.*, 1931, 25, 1011.

MILCH. "Unusual Fractures of the Capitulum Humeri and the Capitulum Radii," *J. Bone and Joint Surg.*, 1931, 13, 882.

PATTERSON. "Treatment of Displaced Transverse Fractures of the Head of [illegible] *Bone and Joint Surg.*, 1934, 16, 695.

[illegible] the Head and Neck of the Radius," *Brit. J.*

JEFFERY, C. C. "Fractures of the Head of the Radius in Children," *J. Bone and Joint Surg.*, 1950, 32B, 315.

Radial Epiphysis

THU[illegible] [illegible] Note on the Injuries to the Distal [illegible]" *Proc. Roy. Soc. Med.*, 1929, 22, 695.
AITKEN, A. P. [illegible] "Fractured Distal Radial Epiphysis," *J. Bone and Joint Surg.*, 1935, 17, 302.
KEY, J. A. "Survival and Growth of an Epiphysis after Removal and Replacement," *J. Bone and Joint Surg.*, 1949, 31A, 150.

complete fracture of the lower fourth of the bone, described under fractures of the shaft.

TREATMENT. Where the displacement is small a supporting plaster for two weeks is sufficient, but where displacement has occurred it must be corrected by manipulation and a forearm



FIG. 371. Lateral view of the same case, showing crumpling of the posterior compact bone More often the anterior side of the radius crumples.

plaster applied for three weeks. In children exercises are unnecessary.

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MCMASTERS, P. E. "Late Ruptures of the Extensor Pollicis Longus and Flexor Pollicis Longus Tendons following Colles's Fracture," *J. Bone and Joint Surg.*, 1932, 14, 93.

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PATTERSON. "Treatment of Displaced Transverse Fractures of the Head of the Radius in Children," *J. Bone and Joint Surg.*, 1934, 16, 695

MURRAY, R. C. "Fractures of the Head and Neck of the Radius," *Brit. J. Surg.*, 1940, 28, 106.

FRACTURES OF THE TIP OF THE OLECRANON may arise from direct violence. They are rare. More commonly a small bony spur, or osteophyte, is knocked off. In children after the age of ten the centre for the tip of the olecranon may be knocked off, an essentially similar lesion. A sling for a fortnight is usually sufficient treatment.

FRACTURES OF THE STYLOID PROCESS are most commonly associated with a Colles's fracture of the radius. They may, however, arise from ligament strain in severe wrist sprains, and from direct violence.

Where due to direct violence strapping is sufficient, but those associated with severe sprains require more serious attention. It is advisable to immobilise the wrist in plaster for a fortnight as non-union of the fragment and persistent pain are common (see p. 377).

Fractures of the Olecranon through the Sigmoid Notch

TYPE OF VIOLENCE. These fractures most commonly arise through direct violence from falls on the point of the elbow. In this

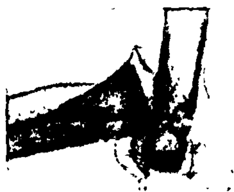


FIG. 372. Forward dislocation of the elbow with fracture of the olecranon.

case the fracture is usually transverse, lies at the centre of the sigmoid notch, and frequently shows no displacement. Should muscular contraction of the triceps have succeeded the fracture, or should the fracture be due to the pull of the triceps snapping the ulna over the lower end of the humerus, the fragment may be widely displaced and the fibrous expansions on either side of the insertion of the muscle widely torn. The position is thus analagous to that occurring in fractures of the patella. Fractures may however occur from the weight of the body being transmitted to the sigmoid notch when the forearm, but not the elbow, is supported (Fig. 372). Under these circumstances either an oblique fracture such as is shown in Fig. 375 occurs or a transverse fracture near the coronoid occurs (Fig. 379) with anterior subluxation of the elbow. In the latter case the antero-posterior stability of the elbow joint is seriously compromised.

CHAPTER XXIII

FRACTURES OF THE ULNA, AND BOTH BONES OF THE FOREARM

THE ULNA

Surgical anatomy. The ulna occupies a peculiar position in the forearm, providing the pivot around which the radius turns, but not taking any compression strain, which is borne by the radius. Its readily palpable subcutaneous border is uppermost when the arm is used to shield the face, and so the bone is frequently the recipient of direct violence, and fractures are commonly compound.

CONSIDERABLE discussion has surrounded the decision as to which bone it is most important to reduce accurately. For sound function of the forearm it is important to reduce both perfectly, but *if comminution or compound injuries limit consideration to one bone,* then the ulna is the most important to align. The axis of rotation of the radius is thus restored and the ends of the radius will be pulled into moderately good position by the ligaments attaching them to the ulna. A fair degree of pronation and supination is thus likely to be restored. Minor degrees of mal-alignment of the radius or ulna will be repaid by traumatic arthritis at one or other radio-ulna joint a few years later.

Classification of fractures of the ulna. 1. Fractures of the small processes of the ulna :

(*a*) Coronoid
(*b*) Olecranon. (Tip)
(*c*) Styloid.

2. Fractures of the olecranon through the sigmoid notch
3. Fractures of the shaft of the ulna.
   (*a*) Alone.
   (*b*) Associated with a dislocation of the head of the radius
   (*c*) Associated with fractures of the radius. (Both bones.)

Fractures of the Small Processes

FRACTURES OF THE CORONOID PROCESS OF THE ULNA arise from tendon strain in over-extension of the elbow, or from injury by the lower end of the humerus in posterior dislocations of the elbow. The displacement of the fragment is variable, but it can best be returned to position by acute flexion of the arm. Following dislocation this may be a dangerous procedure, and it may have to be done gradually as the swelling subsides. The position is maintained for three weeks and then movements gradually commenced.

DIAGNOSIS. The lesion produces local pain with an inability to straighten the arm, and usually a characteristic swelling over the olecranon due to effusion of blood into the olecranon bursa and



FIG. 379. A transverse fracture at a more proximal level, in which it is feared that removal may render the elbow unstable.



FIG. 380. This fracture may be treated by a single screw, though if it or the fragments of the comminuted fracture are excised and the triceps brought down to the fracture surface, the formation of new bone in the tissues and firm fibrosis usually makes the joint stable.

surrounding tissues. It is occasionally difficult to exclude this fracture in the presence of a typical history when there is blood clot or loose bodies in the olecranon bursa. The simulation of a fracture line may be very confusing and require an X-ray to differentiate it.



FIG. 381. Fracture of the olecranon without displacement due to direct violence.

Owing to the subcutaneous position of the bone, fractures are occasionally compound.

TREATMENT. *Cases with no displacement* are immobilised in plaster with the elbow 45° to 60° short of full extension, which is more comfortable than the completely extended position. This position is maintained for three weeks, when a sling is substituted



Fig. 373. Transverse fracture of the olecranon tip.

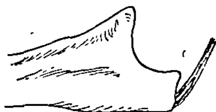


Fig. 374. This fracture is best treated by excision of the fragment and attachment of the triceps to the fracture surface.

With any of these injuries comminution may occur, or one form of violence may succeed another.

Fractures of the olecranon can thus be divided up into four groups :—

1. Fractures involving the attachment of the triceps and the posterior third of the sigmoid notch which do not imperil the



Fig. 375 Oblique fracture of the base of the olecranon often accompanied by forward dislocation of both bones of the forearm.



Fig. 376 Correct and simple method of fixation by a single screw. (See Fig. 384).

stability of the elbow and can be treated by excision of the fragment (Figs 373, 374)

2 Fractures of the middle of the notch without displacement which can be treated expectantly (Fig. 381).

3 Fractures, usually oblique, which involve the middle third of the notch and upset the stability of the joint, and which do not lend



Fig. 377 Comminuted fracture of olecranon.



Fig 378 Comminuted fracture of olecranon treated by long single screw or bone graft.

themselves to excision These are best treated by single screw fixation

4. Fractures which may be comminuted, involving the anterior third of the sigmoid notch, and gravely imperil the stability of the joint. These must be treated by restoration of the fragments to their normal position if possible.



FIG. 383. An oblique fracture of the olecranon.

bone peg may be substituted. The screws may be uncomfortable later because of their subcutaneous position and because they interfere with the olecranon bursa. They may always be removed easily. After accurate suture of the skin the elbow is covered with a pressure bandage and the whole enclosed in a light plaster case from axilla to metacarpal heads. The elbow is placed at an angle of 90 to 135 degrees, depending on the amount of relaxation of the triceps required. The plaster is removed at the end of a fortnight and the stitches removed. Subsequent treatment depends on the rigidity of fixation achieved. In oblique cases with a single screw fixation, gentle movements may be commenced at this stage and the forearm merely supported in a sling. In other cases further immobilisation in plaster for a fortnight may be required.

TRANSPLANTATION OF THE TRICEPS INSERTION. Recently removal of the olecranon has been practised with considerable success. It appears to be more satisfactory than the corresponding removal of the patella for fractures of the patella. In either case the important feature of the operation is the union of the expansions of the muscle, in this

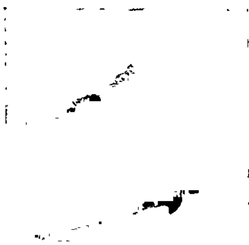


FIG. 384. An oblique fracture fixed by a single screw.

and movements within it allowed. This is discarded in two more weeks. The result is usually very satisfactory, though a few cases take time to recover full extension.

Fractures with displacement. These must be operated on to restore the structure of the joint accurately and unite the torn aponeurosis. Occasionally in comminuted fractures it is necessary to operate in the absence of wide separation of the fragments because a small fragment is tilted into the joint.

Operative treatment. The approach is from behind through a curved incision. This may be curved transversely, or longitudinally,



FIG. 382. A transverse fracture of the olecranon with displacement.

and is so arranged that the fracture line and the incision do not cross one another. A tourniquet may be used if desired. The fragments and torn fascia are exposed and cleared of débris. When their accurate configuration is appreciated, a decision as to the best method of fixation may be arrived at. In transverse fractures a long screw inserted from the posterior surface of the olecranon will usually impact the fragments well and maintain good alignment. In fractures of the anterior third, this is essential to avoid recurrent anterior subluxation. If the fragments are badly comminuted this may be difficult and compromises such as that shown in Fig. 378 may have to be used. In oblique fractures, there are usually a few small fragments which have to be removed before the proximal fragment can be fitted into place. It is then best fixed with a single oblique screw inserted from the subcutaneous surface of the olecranon. Wire may be used, but screws are more satisfactory because of their steadying effect, and the impaction they produce. If desired, a thin

violence, and occur in the weak lower third of the bone. The fracture may be transverse, comminuted or oblique. Displacement is, as a rule, small, owing to the bracing action of the radius and tends to be a bowing of the ulna towards the radius, due to muscle pull.

Owing to the ease with which the bone may be palpated, diagnosis is simple. Difficulty may arise in children in whom the break is

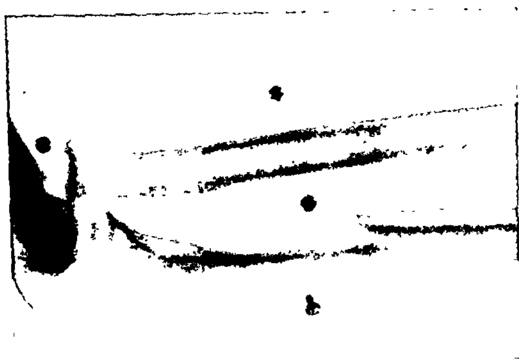


FIG. 387. Fracture of the shaft of the ulna with forward dislocation of the head of the radius. The so-called "Monteggia fracture." The same case as shown in Fig. 38.

greenstick, when false motion cannot be detected. Pronation and supination are painful or lost. In children blows on the inner side of the forearm are liable to produce a greenstick fracture of the ulna with lateral bowing of the bone associated with a lateral subluxation of the elbow and occasionally a fracture of the lateral condyle, or more commonly a separation of the lateral epiphysis.

TREATMENT. When displacement is present the following manœuvres may be tried. Firstly, simple extension, as applied to reduce a Colles's fracture, may be tried with the hand held, however, *in radial deviation* to exert as much traction on the ulna as possible. This is aided by manipulation with the fingers, which try to bow the ulna posteriorly, a move which usually springs the ends apart. *Secondly*, if a screening room is available, a small Steinmann's pin may be inserted under a local anæsthetic and engaged in the bone



FIG. 385. A comminuted fracture of the olecranon, treated by the removal of the proximal fragment.

case the triceps. The operation is planned as for suture, the proximal fragment of bone is removed, and any spicules around the distal end trimmed up. The triceps is then firmly pulled down and united by catgut to the fascia around the ulna. The arm is treated post-operatively in the same manner as after screwing or pegging the fragment. This treatment is suitable for comminuted fractures and in the old, particularly, if there is any osteo-arthritis.

PROGNOSIS. Union is usually rapid and satisfactory. The amount of movement which returns varies largely with the age of the individual. In the young it is usually complete, in older people there may be a permanent loss of 10° to 15° of movement. In a few cases, particularly comminuted fractures, there is a later development of traumatic arthritis. The principal advantage urged for removal of the fractured fragment is freedom from this latter complication. Excision of the proximal fragment is however only suitable for a limited number of cases

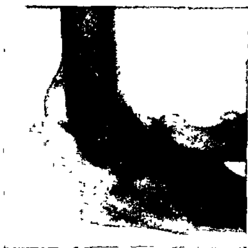


FIG. 386. The previous case after operative removal of the proximal fragment. There is some formation of new bone in the tendon of the triceps, but the functional result is excellent.

Fractures of the Shaft of the Ulna

Fractures of the shaft alone are most commonly due to direct

violence, and occur in the weak lower third of the bone. The fracture may be transverse, comminuted or oblique. Displacement is, as a rule, small, owing to the bracing action of the radius and tends to be a bowing of the ulna towards the radius, due to muscle pull.

Owing to the ease with which the bone may be palpated, diagnosis is simple. Difficulty may arise in children in whom the break is

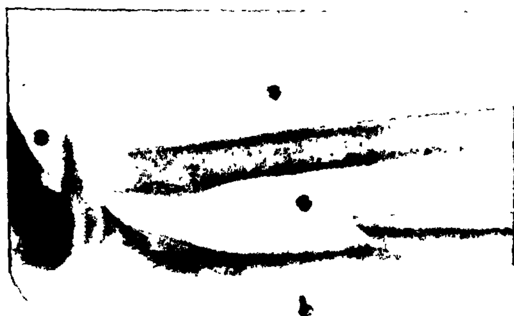


Fig. 387. Fracture of the shaft of the ulna with forward dislocation of the head of the radius. The so called "Monteggia fracture." The same case as shown in Fig. 38.

greenstick, when false motion cannot be detected. Pronation and supination are painful or lost. In children blows on the inner side of the forearm are liable to produce a greenstick fracture of the ulna with lateral bowing of the bone associated with a lateral subluxation of the elbow and occasionally a fracture of the lateral condyle, or more commonly a separation of the lateral epiphysis.

Treatment. When displacement is present the following manœuvres may be tried. Firstly, simple extension, as applied to reduce a Colles's fracture, may be tried with the hand held, however, in radial deviation to exert as much traction on the ulna as possible. This is aided by manipulation with the fingers, which try to bow the ulna posteriorly, a move which usually springs the ends apart. Secondly, if a screening room is available, a small Steinmann's pin may be inserted under a local anæsthetic and engaged in the bone

ends, and used to lever them back into position. Failing this open operation is the last hope. (This is more commonly required to retain position than to reduce the deformity.) Fixation is by an arm plaster, including the elbow held at a right angle, and the forearm in the mid-prone position, the plaster being continued down to the metacarpals, to prevent rotation, and to use radial deviation of the hand, if necessary, as a method of control. In a few cases there is an associated dislocation of the lower radio-ulnar joint which must be reduced, and makes retention of the fragments more difficult. The circular plaster bandage must not be tight as that may bow the ulna toward the radius, and methods to prevent this as in fractures of both bones of the forearm may have to be adopted (see Figs. 399, 400).

The ulna unites slowly and requires immobilisation for four to six weeks in the young, and six to eight weeks in the old. Even then it may not be firm. If it is, a sling is worn for a further fortnight. If it is weak a plaster splint is applied to the forearm only. In cases of delayed union the whole arm plaster is repeated for four weeks and the case reviewed again.

Fracture of the Ulna associated with Dislocation of the Head of the Radius

This fracture was first described by Monteggia in 1814 and bears his name. It consists of a fracture of the ulna in its upper half accompanied by a dislocation of the head of the radius. There are two main varieties :—

1. Associated with *anterior* dislocation of the head of the radius. The fracture is a torsional one, and lies in the upper half of the ulna. It is due to forced pronation of the forearm, which crossing the ulna levers the radial head out of place. If the radial head does not dislocate a fracture of the radius may occur (Fig. 387).

2. Associated with *posterior* dislocation of the head of the radius. This is due to forced flexion of the forearm, and the fracture of the ulna lies just below the expansion for the coronoid process, a little proximal to the site of the pronation fracture.

Occasionally lateral dislocations of the radial head are met with accompanied by ulnar fractures. Continuation of the force after dislocation of the head of the radius may fracture the radius (Fig. 395). These fractures are important because of the instability of the ulnar fracture in many cases which demands operative fixation. A comparable lesion affecting the shaft of the radius and the lower radio-ulnar joint is described on page 363.

Fracture of the head of the radius is not uncommonly associated. The inevitable rupture of the orbicular ligament is not important,

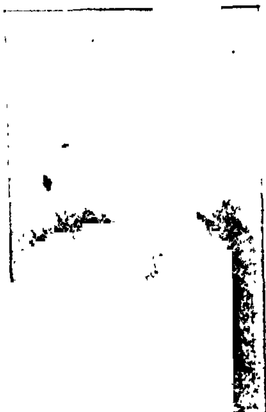


FIG. 388 Greenstick fracture of the upper end of the ulna, with a lateral subluxation of the elbow and the upper radio-ulnar joint.



FIG. 389. Separation of the lower radial epiphysis, showing the small chip of metaphysis usually displaced with it.

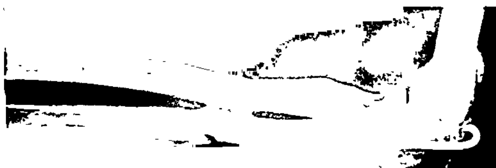


FIG. 390. Fracture of the radius and ulna by the same mechanism as produces a Monteggia fracture. The ulna stabilised by a Rush pin and the radius wired.



FIG. 391. Avulsion fracture of a spur in the triceps attachment to the olecranon.



Fig. 395 Fracture of both bones of the forearm, with posterior dislocation of the head of the radius.



Fig. 396. The same case after reduction There was also a chip fracture of the hea of the radius which required open operatio and removal of the fragment.

patient. Muscle spasm produces shortening and overlap of the fractured ends. The displacement of the radius which may occur is similar to that in fractures of this bone alone, and the ulna tends to bow in towards it. Dislocation of either upper or lower radio ulnar joint may also occur (Figs. 395, 402).

Owing to the peculiar relationship of the upper and lower radio-ulnar joints which permit the complicated movement of pronation and supination, alteration of bony alignment is particularly liable to



FIG. 397. Greenstick fracture of both bones of the forearm.

be followed by limitation of movement, the imposition of strain on the two joints, and subsequent traumatic arthritis. It follows that perfect reduction of the fractures of both bones is necessary if function is to be satisfactory. In children growth will compensate for minor imperfections, but not so in adults, who require the most careful attention if satisfactory results are to be obtained. The difficulties are due to the tendency of the two bones to bow into one another due to muscle pull, and the

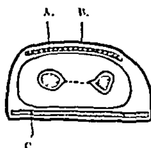


FIG. 400. A second method for avoiding the approximation of the bones at the site of fracture. A narrow board C, which is wider than the forearm, is placed on the inner aspect of the forearm, and held there by the circular bandage B, which also covers the usual plaster slab A.



FIG. 398. Diagram to show the approximation of the forearm bones produced by a circular plaster.



FIG. 399. One method of overcoming the difficulty. Two wooden rods (½ inch × 2½ inches) are pressed into the plaster slabs on either side of the arm, and the whole covered by the circular plaster.

pressure of a circular plaster; the tendency to cross-union in fractures at the same level; the difficulty in reducing both fractures equally well; and the frequent failure to correct rotational deformities Rotational deformity is particularly difficult to correct and most important. It is impossible to check its reduction radiologically, and it can be said with truth that the only way to be certain that it is corrected is to see the interlocking of the bony spicules of the fractured surfaces at open operation.



Fig. 395. Fracture of both bones of the forearm, with posterior dislocation of the head of the radius.



Fig. 396. The same case after reduction. There was also a chip fracture of the head of the radius which required open operation and removal of the fragment.

patient. Muscle spasm produces shortening and overlap of the fractured ends. The displacement of the radius which may occur is similar to that in fractures of this bone alone, and the ulna tends to bow in towards it Dislocation of either upper or lower radio ulnar joint may also occur (Figs. 395, 402).

sary. The ulna tends to bow more readily than the radius and requires stronger fixation to maintain its rigidity. A transverse fracture in the ulna is not satisfactorily fixed by a single screw, but in the radius might be satisfactorily held if the ulna was fixed at the same time. Varying combination of fractures are met with, both transverse at the same level, transverse at different levels, one transverse the other oblique, one oblique the other comminuted, and so on. It is possible to fix one bone, usually the ulna, and if there is



Fig. 401. Fracture of both bones of the forearm with dislocation of the lower radio ulnar joint. A.P. view.



Fig. 402. Lateral view of the same case.

little displacement in the radius leave it alone. Commonly combinations of methods adapted to the type of fracture are employed.

Methods. 1. *Single screw fixation.* Adaptable to oblique fractures and to half oblique, half transverse fractures, and spiral fractures, of either bone. Single screws may be used in transverse fractures to control position when angulation is controlled by fixation of the other bone.

2. *Plates or bone grafts.* These have the advantage of restoring the rigidity of the bone, and this is particularly valuable here. They are most conveniently applied to the ulna, which fortunately is the most important bone to fix, but may be applied to both bones. The radius is cut smooth to facilitate the application of a graft.

DIAGNOSIS. This is usually straightforward. In children there may be very little deformity, but when there is, on account of the incomplete nature of the fracture, it is fixed, and false motion is not detectable.

TREATMENT. Perfect reduction must be kept the goal of all methods. Numerous methods have been devised to achieve this, adaptable to individual cases. Each case is a separate problem, in which the deformity present, the type of fracture, the levels of the two fractures, and the degree of soft tissue injury must be carefully considered and the appropriate decision reached. The available methods will be outlined, the combinations of these methods possible can only be briefly discussed, but will, I hope, be sufficient to stimulate interest in each case as a separate problem.

CASES WITHOUT DISPLACEMENT. It is necessary here to avoid deformity from the pull of muscles, the action of gravity, and the pressure of the splint. The forearm is steadied by gentle traction as for a Colles's fracture and a plaster applied from the metacarpals to the elbow. It is subsequently continued above the elbow when the traction is released. Two methods may be adopted to avoid the pressure of the circular bandages narrowing the interosseous space, and these are shown in Figs. 399 and 400. The forearm is most satisfactorily treated in the mid-prone position, which relaxes as many muscles as possible. Full supination has the advantage of maintaining the interosseous space at its widest, but this is not necessary in cases in which there is no danger of cross-union. In all other cases, however, supination is a safer position than pronation, not only for the reason given, but because pronation can be compensated for by the shoulder, while supination cannot. The plaster having been completed is carried in a sling. It is replaced as soon as it becomes loose, careful watch being kept for angulation by check radiographs. Its occurrence demands replaster or the adoption of a method in which retention is better controlled.

CASES WITH DISPLACEMENT. Reduction may be carried out under anæsthesia in a similar manner, or by the use of skeletal traction (Fig. 396). The wires are inserted in the olecranon and through the metacarpal heads, or through the lower end of the radius and the ulna. By traction and manipulation under radiological control a fairly good position of the bones can usually be achieved, though rotation is still likely to remain uncorrected. The chief disadvantage is the liability to recurrence of the displacement as soon as the traction is released, while inside the plaster. In order to maintain control of the bones the wires may be incorporated in the plaster, thus making use of fixed distraction. This is undesirable anywhere, and particularly in the forearm where it is likely to lead to non-union of the ulna. Control of the fragments by pins, which screw into the bones, and enable the angle of the fracture to be controlled, and which can be incorporated in the plaster is more satisfactory, but seldom produces perfect reduction.

Open operative methods. Three principles must be borne in mind; early and perfect reduction, minimum soft tissue disturbance, and the imparting of sufficient rigidity to the bones by the fixation used to render the need for plaster except as a protection unneces-

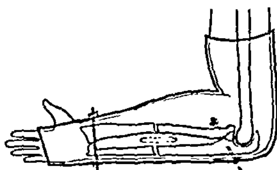


FIG. 406. Fixation of the forearm in difficult fractures with two thin Steinmann's pins, incorporated in the plaster. The dotted line indicates the site for the wooden rods described in Fig. 399.

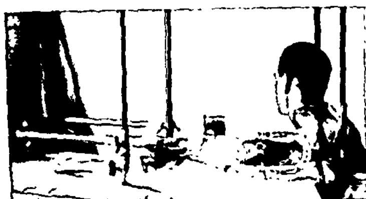


FIG. 407. The use of the Böhler leg frame for traction in cases of fracture of the forearm. The patient is under brachial plexus anaesthesia. One wire runs through the metacarpal heads, the other through the olecranon.



FIG 408. The same case with the plaster applied over the wires which are removed when it has set.

are then accurately reduced and the nail pushed across the fracture line to lock the bones in position. The forearm is then put in plaster leaving the nail protruding. When union is firm enough to prevent rotation and deformity the nail is removed, usually between the fourth and sixth week.

3. *Intramedullary nail or wire.* This is a particularly useful method for the ulna, where the wire can be brought out through the olecranon, but is less satisfactory in the radius where it must be



Fig. 403. Reduction and fixation of previous case by an intramedullary Kirschner wire in the ulna, and single screw in the radius. A.P. view.



Fig. 404. Lateral view of same case.



Fig 405. Use of [illegible]
bones of [illegible]
open oper[illegible]

brought out in the vicinity of the styloid process. The bones are exposed as for open operation but through a much smaller incision, a long sterile nail is introduced down the proximal fragment and made to protrude through the olecranon. It is withdrawn till the end just disappears from view at the fracture line. The two bones

CHAPTER XXIV

FRACTURES AND DISLOCATIONS OF THE CARPUS

Surgical anatomy. The complex articulation of the carpal bones allows an injury the choice of many joint paths, and this, combined with the fractures of the bones which may be associated, allows a multiplicity of lesions to be developed. As a guide to these the following points must be noted. The proximal bones of the wrist, navicular, lunate, and triquetrum, each have a large doubly curved articular area for articulation with the lower end of the radius, and the triangular fibrocartilage. This area is more extensive on the dorsum, and it allows flexion and extension, and abduction and adduction at the wrist. The large area of articulating bone, consequently renders dislocation at this level more frequent than at the intercarpal or carpo-metacarpal level.

The capitate fits into a socket formed by the navicular, lunate, and hamate, and terminal flexion and extension of the wrist occurs at this joint. It is strongly resistant to lateral strain, but anterior or posterior dislocation may occur at this level. The navicular lies as a lynch pin across the two carpal rows, strongly articulated with each row, and forming a bony link between them. It follows that in strains on the intercarpal joint it is subjected to heavy sharing forces, and not infrequently breaks at the waist, such a fracture being accompanied by displacement. In the more common lesion of the navicular, it is merely squeezed violently between the carpal bones and the lower end of the radius. This results in a fissure of the cancellous bone, the deformity produced being insufficient to rupture the cartilaginous capsule of the bone, and displacement is negligible. These are the fractures which it is difficult to see radiologically. The articulation of the carpo-metacarpal joints is an irregular line, which will similarly resist lateral strain, but is susceptible to dislocation in the A.P. plane. The first metacarpal has a separate saddle-shaped joint, where it articulates with the multangulum major.

As it is impossible in a book of this size to go into the numerous lesions which occur in the carpus they will be briefly listed, and then the more common and important lesions described. The figures given, taken from Schnek, indicate the frequency of the lesions.

Fractures

Navicular. Old and new. 234.
Lunate. Body and posterior process. 82. (Too high. *Fractures of* posterior tubercle of triquetrum were included.)
Triquetrum. 18. (Too low.)
Pisiform. 13.
Multangulum major. 13.
Hamate. 10.
Capitate. 6.
Multangulum minor. 1.

In Figs. 390, 403 different combinations of the methods described which produced satisfactory results are shown.

Union is slow, taking four to eight weeks in children and six to twelve weeks in adults. The nearer the fracture to either end of the bone the more rapid the union. Delayed union is common, and is treated by repeated plasters by Beck's drilling. An unusual and serious complication is the occurrence of cross union between the bones, due to the hæmatoma around both bones being continuous. Ossification occurs in this, and the bones become connected by a firm bar which prevents pronation and supination. After time has elapsed for this bone to become well organised its operative removal is the only hope of cure.

Separation of the epiphyses of both bones. This may occur up to the age of sixteen years. The treatment is similar to that of separation of the radial epiphysis alone. The ulnar epiphysis being firmly attached to it, they are easily reduced together and the position maintained by a short forearm plaster, with the hand in slight palmar flexion.

FURTHER READING

Fractures of the Olecranon

NAUGHTON DUNN. "Operation for Fracture of the Olecranon," *Brit. Med. J.*, 1939, **1**, 214.

General

HEIN. "Fractures of the Forearm," *J. Bone and Joint Surg.*, 1935, **17**, 272.
SOWLES. "End Results of Fractures of Both Bones of the Forearm," *J. Bone and Joint Surg.*, 1934, **16**, 193.
CUNNINGHAM. "Fractures of the Ulna and Dislocation of the Head of the Radius," *J. Bone and Joint Surg.*, 1934, **16**, 351.
NAYLOR, A. "Monteggia Fractures," *Brit. J. Surg.*, 1942, **30**, 323.
SMITH, F. M. "Monteggia Fractures," *Surg. Gynæ. and Obstets.*, 1947, **85**, 630–640.
KNIGHT, R. A., and PURVIS, G. D. "Fractures of Both Bones of the Forearm in Adults," *J. Bone and Joint Surg.*, 1949, **31A**, 755.
EVANS, E. M. "Pronation Injuries of the Forearm," *J. Bone and Joint Surg.*, 1949, **31B**, 578.
PENROSE, J. H. "The Monteggia Fracture with Posterior Dislocation of the Radial Head," *J. Bone and Joint Surg.*, 1951, **33B**, 65.
EVANS, E. M. "Fractures of the Radius and Ulna," *J. Bone and Joint Surg.*, 1951, **33B**, 548.
BURMAN, M. "Primary Torsional Fracture of the Radius and Ulna," *J. Bone and Joint Surg*, 1952, **34A**, 665.

radiological evidence of fracture no external evidence of fracture can be seen. These cases form 80 per cent. of the cases met with and do extremely well if immobilised in plaster. It is obvious from the fact that the cartilaginous envelope is nearly always partly intact that it is unnecessary to fix the thumb in the plaster case to obtain adequate rest for union to occur.

2. FRACTURES OF THE WAIST WITH DISPLACEMENT. These are due to fracture of the bone associated with a subluxation or sprain of the mid-carpal joint, the navicular being snapped as the connecting link between the two rows. (Compare with peri-lunar dislocation of the wrist.) The displacement is obvious or appears immediately or after a short interval as an elliptical clear space between the bones. In the past this has often been considered to be a sign of bone erosion at the fracture line, but is due to the shadows produced by the overlying margins of the fractured bone as the central ray passes obliquely through the fracture site. It is an indication of displacement and there is consequently greater risk of non-union. These cases demand reduction and a longer period of immobilisation to secure union. To be safe it is necessary to immobilise the thumb to exclude all possibility of movement at the wrist.

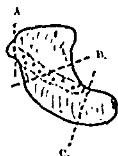


FIG. 409. Fracture sites in the *navicular*.
A. Fracture of the tuberosity.
B. Fracture at the "waist," cutting the line of the nutrient foramina.
C. Fracture proximal to the line of blood supply.

Avascular necrosis. Failure of the blood supply to the proximal fragment results in a delay in union and may result in avascular necrosis of the proximal pole. This is a serious complication as it prevents union and usually results in a rapid breakdown of the radio-carpal joint. The blood supply to the navicular enters the dorsal surface along a groove which crosses the waist of the bone obliquely and leaves the proximal pole to obtain what nourishment it can through the navicular-lunate ligament. It is owing to the fact that this pole is largely covered in cartilage that a blood supply cannot develop through the formation of adhesions. The cartilaginous portion of the bone survives in the tissue fluids, thus making an effective barrier to revascularisation from that area. Revascularisation can thus come only through the fracture line, or the navicular lunate ligament. Not all fractures through the proximal pole, and only a few through the waist, show avascular necrosis and its onset is determined by other factors than the fracture itself. Avascular necrosis manifests itself by the series of changes previously outlined (p 18), and finally by a hypercalcification of the fragment. In this event the removal of the fragment may be indicated, though

Dislocations.

Lunate. Old and new. 25.
Lunate and navicular dislocated. 10.
Dislocation of the lunate and fracture of the navicular. 7.
Pisiform. 6.
Triquetrum. 1.
Capitate. 1.
Dislocations of the wrist, anterior and posterior, at the carpo-metacarpal, carpo-carpal, and radio-carpal joints occurred only once each.

In discussing these lesions the general principles will be first outlined, and then the individual, more important bones mentioned.

In the case of fractures there is generally little displacement, and the treatment consists in immobilising the wrist in moderate dorsiflexion until clinical and X-ray evidence shows that the bone has united. This will be elaborated in the description of fractures of the navicular. In fracture-dislocations the dislocation is reduced. This is usually accomplished by steady traction, under local or general anæsthesia, accompanied by manipulation and pressure with the fingers. At the same time any displacement of an associated fracture is reduced, and the case is then treated on the merits of the fracture. In dislocations alone the reduction is accomplished as outlined, and the wrist then immobilised in plaster for three to five weeks, while exercises as for a Colles's fracture are carried out.

Fracture of the Navicular (Scaphoid)

This is the most commonly injured bone in the wrist, the body being broken in the transmission of force from the hand to the radius Fractures of the navicular consist of fractures of the tuberosity and of the proximal pole of the bone, forming 12 per cent. of all cases, the remaining large majority (88 per cent.) being fractures of the waist of the bone. These are the most important and interesting group and are subdivided into two great classes.

1. Fractures of the waist without displacement. These are due to falls on the hand in which the weight is transmitted through the navicular to the radius. The bone is squeezed between the carpus and the radius, but cannot be deformed or displaced. being well supported on all sides. As a result a crack in the cancellous bone occurs, which in a great many cases does not involve the cartilaginous envelope of the bone As a result the fragments are held in exceedingly close apposition and difficulty may be found in discovering the fracture in the first radiograph. The importance of the central ray lying in the plane of the fracture is obvious and three or more views are necessary to ensure this These facts have often been proved at operation, where in spite of

of the styloid process of the ulna, or the bone may be involved with others in complex crushing injuries.

X-RAY INVESTIGATION. The films must be of good definition, and of sufficient detail to show the bony trabeculæ. Owing to the fact that the fracture line is sometimes oblique it may not show up in certain positions, so that it is necessary to radiograph the wrist in an oblique position as well as the lateral and A.P. positions. The fracture may be obvious or require a careful search with a lens. In searching, the thin layer of compact bone must be accurately followed. When, in spite of a negative X-ray, signs and symptoms remain, the wrist should be rested in plaster for three weeks and then re-X-rayed. If a fracture has been present there will be sufficient decalcification along the line of fracture to make it obvious in the second radiograph (Fig. 415).



FIG. 411. Plaster for fracture of the navicular.

Later films may show varying degrees of sclerosis and rarefaction in the bone which may be interpreted as the sequelæ of vascular changes around the fracture line. This has been mentioned especially in connection with the small fragment near the lunate. Both rarefaction and patchy sclerosis on either side of the fracture line will disappear with adequate immobilisation, and healing can only be said to be complete when trabeculæ can be seen to cross the line of fracture. Sclerosis of a uniform and continuous type on either side of the fracture line is a sign of complete non-union and an indication that unless some treatment is given bony union will never occur, and is going to be very difficult to achieve if treatment is instituted.

The significance of the elliptical shadow appearing at the fracture line has already been mentioned. Gauging union is not always easy, and a decision to allow use of the wrist is often based more on the absence of signs of delayed union in a case adequately treated than on definite appearances of union.

Treatment

Cases without displacement. Firm fixation in a plaster, which extends from just below the elbow to the heads of the metacarpals, with the hand in moderate dorsiflexion, and the wrist slightly ulnar adducted, will, if maintained long enough, result in union in all but late cases. There is considerable discussion as to the necessity for immobilising the thumb. In unskilled hands it is possibly safer to include the thumb metacarpal in the plaster, but we have had

some remove the whole bone. If gross traumatic arthritis of the wrist is present it is probable that the case will go on to an arthrodesis of the wrist.

The fracture has gained a bad reputation from the fact that a great many cases have been unrecognised, and consequently inadequately treated, and many cases have been treated over an insufficient length of time to obtain union. Ununited fractures of the navicular are painful, and result in a feeling of weakness in the wrist, while in cases in which the proximal fragment undergoes necrosis a seriously disabling arthritis of the wrist is set up, which will be sufficient to totally incapacitate a working man. Recently it has been shown that prolonged immobilisation will cure the most obstinate cases unless sclerosis of the fracture line is present, or there is degeneration of portion of the bone.



FIG 410. Testing for fracture of the navicular. Weight bearing on the thenar placed on the corner of the table produces pain.

DIAGNOSIS. Following a story suggestive of Colles's fracture the patient will be found to complain of pain which will be maximum over the "anatomical snuff box," *i.e.*, directly over the navicular, this being the most important clinical sign. In most cases the fact that the lower end of the radius is free from tenderness can be found by careful pressure. The swelling is confined mainly to the radial side of the wrist, and the *obliteration of the anatomical snuff box* is easily seen by comparison with the opposite wrist. All movements of the wrist are painful, but abduction particularly so There is pain on gripping and weakness of the grip, and there is always pain if the patient is asked to press firmly on the thenar eminence Once seen the syndrome will be readily recognised, but a few atypical cases occur, and any lesion of the wrist displaying one or more of the features mentioned justifies an X-ray examination of the wrist.

DIFFERENTIAL DIAGNOSIS. Lesions producing a similar picture may be a severe sprain, fracture of the tuberosity of the navicular, fracture of the tip of the radial styloid process, and fractures of the base of the first metacarpal. Rarely the navicular is fractured in association with other lesions, which may be dislocations of the lunate, or of the wrist, fractures of the lower end of the radius, or

improvement. The wrist is X-rayed and if there is evidence of obliteration of the fracture line, and particularly if trabeculæ can be seen to cross the fracture line, union can be said to be sound. The changes in the bone outlined previously must be watched for, and if found demand further immobilisation, till they have cleared up or become permanent, when other methods must be used. Union at the end of seven weeks is often sound, if not the wrist is immobilised as before for a further four weeks. At the end of this period the examination is repeated, and, if satisfactory, the patient is given a clinical trial of the unsupported wrist ; if unsatisfactory, the plaster is repeated. This is continued up to a period of six months, when the most obstinate fractures will usually have united.

NON-UNION. If the patient on clinical trial gets increasing pain in the wrist with use it is a sign that the union is incomplete and the X-rays are carefully re-examined and the wrist further immobilised for four weeks.

Delay in union may be due to : (1) Late instigation of treatment. (2) Inadequate immobilisation. (3) Avascular degeneration in portions of the bone. (4) General bony degeneration in arthritic wrists.

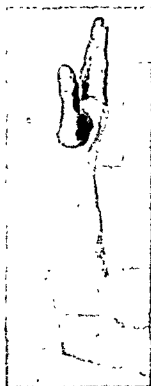
In the first two groups continued and more satisfactory immobilisation can be tried if there is no evidence of established non-union, *i.e.*, sclerosis of the fracture surfaces with smoothing off of their outlines, and even the formation of a thin layer of compact bone. If these are present further immobilisation is useless and the functional capacity of the wrist should be given a clinical trial. In many cases in which no heavy demands are placed on the wrist the result will be moderately satisfactory. If it is unsatisfactory, excision of the proximal pole or of the whole navicular may be carried out, though this is not likely to produce a strong wrist, it may relieve pain. After six months' immobilisation there is little value in keeping the wrist further immobilised, and a clinical trial should be given as in the case of established non-unions.

Where avascular necrosis has been the cause of the non-union, excision of the proximal pole should be carried out. The earlier this is done, *i.e.*, the less the degree of established arthritis the better the result. These cases are best treated by immediate excision of the proximal pole as soon as avascular necrosis is diagnosed, that is in the first four to six weeks. Where there is a general arthritic condition in the wrist, ankylosis is the only alternative to palliative measures such as the wearing of a moulded wrist support or wrist strap

Fractures with displacement. Satisfactory reduction is not easy to accomplish in any case with displacement in two planes If the displacement is in one plane the position can often be made satisfactory by putting the hand in ulnar deviation. It is the displace-

no difficulty in obtaining bony union in the usual time in cases in which the thumb has been left entirely free. In such cases more than usual care was taken that the plaster fitted accurately around the outer side of the fifth metacarpal and the thumb side of the second metacarpal, so that abduction and adduction at the wrist were completely prevented, and the firm bar across the palm of the hand was carefully watched and renewed as soon as a tendency was





Figs [illegible] plaster shown in Fig 411 is safer.

shown for the hand to come away from the plaster. This usually necessitated a renewal of the plaster at the end of the first week when the swelling had subsided, and again as often as was necessary. In a man doing heavy work the thumb metacarpal should be included in the plaster (Fig 411) If the patient's work necessitates putting the hand in water, "Castex," a compound of cellulose in acetone, may be used. It is slow in drying, but impervious to water.

During the period of immobilisation in plaster it is necessary, particularly in the old, to give exercises to the fingers and other joints of the arm as in cases of Colles's fracture. Immobilisation is carried out on these lines for seven weeks, the plaster is then removed, which gives opportunity to inspect the skin and estimate the clinical

improvement. The wrist is X-rayed and if there is evidence of obliteration of the fracture line, and particularly if trabeculæ can be seen to cross the fracture line, union can be said to be sound. The changes in the bone outlined previously must be watched for, and if found demand further immobilisation, till they have cleared up or become permanent, when other methods must be used. Union at the end of seven weeks is often sound, if not the wrist is immobilised as before for a further four weeks. At the end of this period the examination is repeated, and, if satisfactory, the patient is given a clinical trial of the unsupported wrist ; if unsatisfactory, the plaster is repeated. This is continued up to a period of six months, when the most obstinate fractures will usually have united.

NON-UNION. If the patient on clinical trial gets increasing pain in the wrist with use it is a sign that the union is incomplete and the X-rays are carefully re-examined and the wrist further immobilised for four weeks.

Delay in union may be due to : (1) Late instigation of treatment. (2) Inadequate immobilisation. (3) Avascular degeneration in portions of the bone. (4) General bony degeneration in arthritic wrists.

In the first two groups continued and more satisfactory immobilisation can be tried if there is no evidence of established non-union, *i.e.*, sclerosis of the fracture surfaces with smoothing off of their outlines, and even the formation of a thin layer of compact bone. If these are present further immobilisation is useless and the functional capacity of the wrist should be given a clinical trial. In many cases in which no heavy demands are placed on the wrist the result will be moderately satisfactory. If it is unsatisfactory, excision of the proximal pole or of the whole navicular may be carried out, though this is not likely to produce a strong wrist, it may relieve pain. After six months' immobilisation there is little value in keeping the wrist further immobilised, and a clinical trial should be given as in the case of established non-unions.

Where avascular necrosis has been the cause of the non-union, excision of the proximal pole should be carried out. The earlier this is done, *i.e.*, the less the degree of established arthritis the better the result. These cases are best treated by immediate excision of the proximal pole as soon as avascular necrosis is diagnosed, that is in the first four to six weeks. Where there is a general arthritic condition in the wrist, ankylosis is the only alternative to palliative measures such as the wearing of a moulded wrist support or wrist strap

Fractures with displacement. Satisfactory reduction is not easy to accomplish in any case with displacement in two planes. If the displacement is in one plane the position can often be made satisfactory by putting the hand in ulnar deviation. It is the displace-



Fig. 414. Fissure fracture of the navicular waist.



Fig. 415. X-ray film of a fracture of the navicular three weeks after the accident. The fine fissure fracture in the films at the time of the accident was overlooked. Now rarefaction around the fracture line shows up clearly.



Fig. 416. Ligament traction fracture of the dorsal tubercle of the triquetrum Old case in which the fragment appears like a sesamoid



Fig. 417. Fissure fracture of the lunate, showing some early sclerosis in the distal fragment

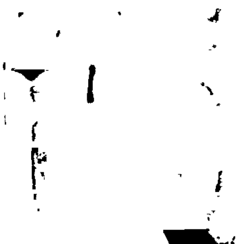


FIG. 418. Fracture of the navicular with displacement.



FIG. 419. The same case after reduction. This must be checked in the lateral and oblique views as well as the A.P.

ment present in the lateral view which is difficult to control, because it depends on a disturbance of the mid-carpal joint. The immobilisation in these cases must be absolute, and the plaster must be carried up to include the metacarpal and the proximal phalanx, leaving only the distal phalanx free to flex.

Both open and closed methods of grafting the navicular have been tried, both operations demanding special skill. Unfortunately though the immediate results of grafting appeared fair, the long term results are bad, due to the development of a radio-carpal arthritis and the method has been almost entirely given up.



FIG. 420. Fracture of the tuberosity of the navicular.



FIG. 421. Perilunar dislocation of the wrist (Fig. 429) accompanied by fracture of the navicular and followed rapidly by the appearance of Kienbock's disease of the semilunar.



FIG 414. Fissure fracture of the navicular waist.



FIG. 415. X-ray film of a fracture of the navicular three weeks after the accident. The fine fissure fracture in the films at the time of the accident was overlooked. Now rarefaction around the fracture line shows up clearly.

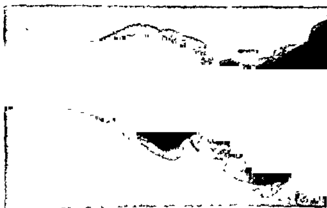


FIG. [illegible] fracture of the dorsal



FIG. 417. Fissure fracture of the lunate, showing some early sclerosis in the distal fragment.



Fig. 422. Fracture of the posterior tubercle of the triquetrum.



Fig. 423. Fracture of the posterior tubercle of the triquetrum associated with a perilunar dislocation of the wrist.

the radius, fractures of the other carpal bones, and in carpal dislocations.

Treatment. Fissure fractures of the bone should be treated in a similar manner to fractures of the navicular of which they are the ulnar counterpart. Fractures of the tubercle and the tuberosity correspond to fracture of the tubercle of the navicular and should be put in plaster with the wrist in the neutral position for three weeks. Clinical non-union of the dorsal tubercle is common, but usually symptomless.

Avascular necrosis, or changes similar to Kienbock's disease, are unknown in this bone.



Fig. 424. Fracture of the posterior tubercle of the triquetrum of the posterior pole of the lunate.

Displaced fractures of the navicular have a much worse prognosis than the undisplaced, due to the frequency of non-union, and increased risk of avascular necrosis. Where necrosis of the proximal pole develops, early excision is recommended, as in undisplaced fractures. A longer period of immobilisation is necessary if union is to occur, and this may take as long as twelve months. Again, positive evidence of non-union makes persistence in immobilisation useless, and the wrist should be given a trial, as it may function moderately well with fibrous union. Late grafting will produce even more unsatisfactory results than early grafting. Treated as outlined only a very small percentage will show such a degree of arthritis that the patient is seriously crippled, and demands further treatment. This may consist of excision of the proximal carpal row, or arthrodesis of the wrist. Recently excision of the radial styloid has been tried to relieve cases with a localised arthritis, but it is too early to speak of the results.

Fractures of the tuberosity of the navicular are rarer than fractures of the body. The symptoms resemble a mild fracture of the body and the lesion is detected on the antero-posterior X-ray film. Immobilisation for three weeks in the position used for fractures of the body produces union with no disability.

Fractures of the Triquetrum (Cuneiform)

This is a comparatively common lesion and forms 3½ per cent. of all cases of wrist injury. In the past it has been confused with fracture of the posterior pole of the lunate, and as a consequence its frequency has been underestimated. Injuries to the bone occur by compression, the bone being caught in ulna deviation of the hand, between the other carpal bones and the radius and ulna, or by ligament traction injuries. The attachments of the dorsal carpal ligaments to the dorsal tubercle, or of the ulnar collateral ligament to the tuberosity of the bone being involved. The successful recognition of the lesion depends on good radiography, with at least one additional oblique view of the wrist.

Diagnosis. The condition rarely occurs alone and its signs are usually masked by the associated lesion The most common isolated lesion is the fracture of the dorsal tubercle, which produces swelling and pain localised to the ulnar side of the wrist. There is moderate pain on all movements, but radial deviation and palmar flexion are most painful. Undiagnosed cases may be seen with complaints of chronic sprain and the fragment of the posterior tubercle may be mistaken for a sesamoid in the lateral film (Fig. 416). Injury to the triquetrum should be looked for in association with any fracture of



Fig. 422. Fracture of the posterior tubercle of the triquetrum.

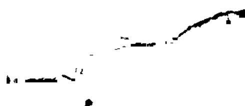


Fig. 423. Fracture of the posterior tubercle of the triquetrum associated with a perilunar dislocation of the wrist.

the radius, fractures of the other carpal bones, and in carpal dislocations.

Treatment. Fissure fractures of the bone should be treated in a similar manner to fractures of the navicular of which they are the ulnar counterpart. Fractures of the tubercle and the tuberosity correspond to fracture of the tubercle of the navicular and should be put in plaster with the wrist in the neutral position for three weeks. Clinical non-union of the dorsal tubercle is common, but usually symptomless.

Avascular necrosis, or changes similar to Kienbock's disease, are unknown in this bone.





Fig. 424. Fracture of the posterior tubercle of the triquetrum of the posterior pole of the lunate.

Fractures of the Lunate (Semilunar)

This bone is the least commonly fractured bone of the proximal carpal row, and its lesions are equally divided between fractures of the posterior pole, often confused with fractures of the dorsal tubercle of the triquetrum and fissure fractures of the body. Fractures of the posterior pole of the bone may occur alone, but usually indicate that there has been marked displacement of the lunate. It may or may not have restored itself to its normal position, so that the fracture may be seen in association with unreduced volar dislocations of the lunate (Fig. 431).

Posterior pole (Fig. 424). This is a ligament traction fracture



Fig. 425 Sclerosis of the lunate following injury, indistinguishable from Kienbock's disease.

and treated in a similar manner to the fractures of the tubercles of the other two proximal carpal bones.

Compression fractures of the body. These may show displacement and narrowing of the bone which is impossible to reduce and which presages an almost inevitable necrosis of the bone and radio-carpal arthritis The addition of the damage of degeneration to that of trauma may be avoided by early excision of the bone, which, while not producing a perfect result, is a great improvement on the usual end result.

Most cases of fracture of the lunate resemble fractures of the navicular in that the fracture occurs within the cartilaginous envelope of the bone and consequently shows little displacement. It may thus be recognised in films taken three weeks later after an apparently normal first radiograph. More commonly the condition is overlooked till avascular necrosis of the bone is [illegible]

condition is indistinguishable from Kienbock's disease, which probably is the same thing (Fig. 425). At operation a loose but broken cartilaginous envelope is found surrounding a dense white core of separated cancellous bone. This lies loose like a pea in a pod, and this detachment is in all probability the reason why a fresh vascular supply fails to develop. In some cases it will be seen that the necrosis only involves part of the bone. At operation these cases will show an intact cartilaginous sheath to the living portion. Excision of the bone produces only moderately satisfactory results as the arthritis in the radio carpal joint tends to spread.

Dislocations of the Radio-carpal Joint

These may occur:

1. Alone (Fig. 426).
2. Associated with fractures or dislocations of the carpal bones.
3. Associated with fractures of the lower end of the radius and ulna.



Fig. 426. Dislocation at the radio-carpal joint. The continuous line indicates the pure dislocation, the dotted line the more commonly associated fractures.

Occurring alone, the lesion is very rare. It is readily reduced by traction combined with antero-posterior pressure, and the wrist is put up in plaster as for a Colles's fracture for four to five weeks.

The difficulty of dislocation associated with anterior and posterior marginal fractures of the radius has been discussed in the chapter on the *radius*.

Dislocation of the wrist is most commonly associated with fracture of the



Fig. 427. Posterior dislocation of the carpus without fracture.

navicular and dislocation of the lunate. The lunate may remain attached to the lower end of the radius by its volar and dorsal ligaments. The line of separation may cross the body of the navicular which is fractured, the small medial fragment of the navicular then remaining in position with the lunate. The wrist is thus dorsally dislocated, leaving the lunate and fragment of the navicular in contact with the radius.

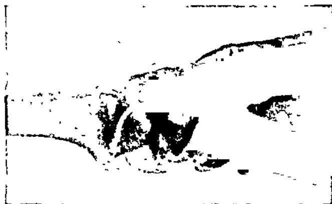


FIG. 428 Posterior dislocation of the carpus, the lunate remaining attached to the radius, a condition identical with that shown in Fig. 423.

DIAGNOSIS. The symptoms resemble those of a severe Colles's fracture. The irregularity of the wrist lies distal to the *styloid processes*, and palmar flexion is grossly limited. There may be inability to extend the fingers, from pressure on the extensor tendons, or to *flex* the *fingers from* the pressure of the dislocated lunate. Both this and median nerve pressure symptoms are much greater in cases in which the lunate alone is dislocated forwards than in the more common case in which the lunate is dislocated with the radius, *i.e.*, the wrist is dislocated dorsally over the lunate.

Reduction in this latter case is relatively easy. Strong traction made by a relay of assistants, combined with manipulation, usually results in the wrist being slipped forwards easily. Traction will obviously be required for a longer time under a local anæsthetic than under a general. A plaster is applied as for a fractured navicular, and similar after-treatment is instituted. If the navicular is not fractured the result is satisfactory in four to six weeks, but if the bone is broken the period of immobilisation is determined by the rate of union of that bone. The onset of degenerative changes in the lunate is denied by Bohler, and this is probably true, the onset of *Kienbock's disease* being due to separation of the cartilaginous envelope.

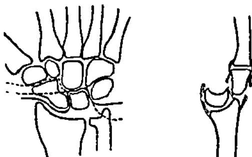


FIG 429. Dislocation of the lunate combined with posterior dislocation of the wrist. The continuous line indicates the pure dislocation, and the dotted line the alternate paths, above the navicular, or through a fracture at the waist of the bone. In the lateral view, note that the posterior ligament of the lunate attaching it to the radius is intact.



FIG. 430. Antero-posterior view of the same case, showing the slight difference from the normal radiographic appearance of the wrist shown in this view.

Dislocations of the lunate. This may occur alone, but it is more commonly due to a spontaneous rectification of a posterior dislocation of the wrist described before. For the lunate to turn forwards it is, however, necessary that the posterior ligament be torn, and this may be done at the time of the dislocation or in the moment of restoration. The lunate is left hanging by the attachment of the anterior ligament alone, and may be turned in almost any direction, as it lies in the carpal canal.

Fig. 431. Anterior dislocation of the lunate, with marked forward rotation.

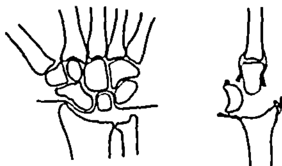


Fig. 432. Anterior dislocation of the lunate. Note that the posterior ligament of the lunate is torn, and the lunate hinges forward on the intact volar ligament, through which its blood supply is maintained.

Symptoms. Those of a severe sprain of the wrist accompanied by local features due to the displacement of the lunate. Thus a depression may be felt where the lunate should lie, on palpation of the dorsum of the wrist. Anteriorly there is a bulge which may be masked by swelling. Pressure on the median nerve with pain and paræsthesia, and inability to flex the fingers from pressure



Fig. 433. Anterior dislocation of the lunate, with less-marked displacement than that in Fig. 431.

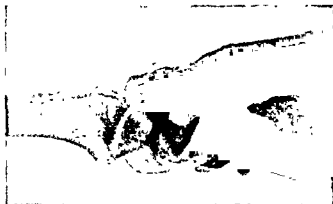


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DIAGNOSIS. The symptoms resemble those of a severe Colles's fracture. The irregularity of the wrist lies distal to the styloid processes, and palmar flexion is grossly limited. There may be inability to extend the fingers, from pressure on the extensor tendons, or to flex the fingers from the pressure of the dislocated lunate. Both this and median nerve pressure symptoms are much greater in cases in which the lunate alone is dislocated forwards than in the more common case in which the lunate is dislocated with the radius, *i.e.*, the wrist is dislocated dorsally over the lunate.

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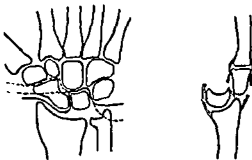


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but has usually to be aided by pressure of the fingers. The type of rotation has much to do with the difficulty of reduction, and the ease of reduction cannot be forecast. If manipulative reduction fails, open reduction must be proceeded with through an incision on the ulnar side of the wrist, between the ulnar and the tendon of the flexor carpi ulnaris. This is best done while the limb is still under skeletal traction. After reduction the wrist is immobilised in the neutral position for three to four weeks. The possibility of late degenerative changes in the lunate appear to be increased if the bone is fractured at the same time, but they are remote in correctly treated cases. The rare case in which the bone cannot be replaced, even under



Fig. 436. Complicated carpal injury. Fracture of the navicular accompanied by anterior dislocation of the multangulum minor and dislocation of the second carpo metacarpal joint. Antero posterior film of the case in *Fig. 436A*.



Fig. 436A. Lateral view of a wrist, showing posterior dislocation of the thumb, from the trapezium (multangulum [illegible]

open operation, demands excision of the bone, but with modern skeletal traction reduction can be obtained in all recent cases.

Complicated injuries to the carpus. These are frequently due to crushing injuries and are consequently often compound. They can only be treated in accordance with the general principles outlined and the wrist immobilised in plaster. Extension splints may be necessary to individual fingers. To reduce swelling the abduction splint or Zeno's position may be useful, and all severe

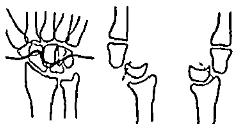


Fig 437. Dislocation at the intercarpal joint.



Fig. 438. Dislocation at the carpo-metacarpal joints

on tendons in the carpal tunnel may be present. Recession of the knuckle of the middle finger is occasionally seen.

TREATMENT. Reduction varies very greatly in its ease of accomplishment



FIG. 434. Dislocation of the lunate under skeletal traction showing the wide space it is possible to obtain for reduction of the bone.



FIG. 435. The final result in a wrist which was seen too late after the dislocation for operative reduction to succeed, and in which the lunate was removed Functionally the wrist, though limited in range of movement, is strong and painless

It is best attempted under skeletal traction with a wire through the metacarpals, just below their heads, and a wire through the olecranon for counter traction. (If this is not available traction as for a Colles's fracture may be used.) X-rays taken during the manipulation will show the increase in the space available for reduction under this method. The return of the bone to its normal position may be accomplished by the pressure of the stretched tendons,

CHAPTER XXV

FRACTURES OF THE METACARPALS AND PHALANGES

Surgical anatomy. The metacarpals and phalanges are small "long" bones, and so are liable to the same varieties of fracture. Of the metacarpals only the first has a freely movable joint at both ends, and so is peculiarly liable to fracture-dislocations. The hinge shaped interphalangeal articulations with their double curve facilitate chip fractures of the base due to ligament strain.

Ossification. Centre for shaft appears in ninth week. Epiphyses for the heads appear at two years and unite at fifteen to twenty years. The first metacarpal is an exception, its epiphysis being proximal and appearing at three years.

Function. The goal of all traumatic treatment is function, and as a secondary condition stability. In the hand in particular the functional use of the fingers must be kept in mind. The multiple small joints lend themselves particularly to stiffness developing from unresolved blood and tissue exudates. Two points must be continually borne in mind in the treatment of the hand. First the function of the hand, if not upset seriously by the fracture, should not be disturbed by splinting. In other words, splinting of metacarpal and phalangeal injuries should be avoided if possible and active use of the fingers encouraged. It is surprising how often a fracture is stable, or after reduction remains sufficiently stable to dispense with splinting. Secondly, if the hand must be splinted, this must be the minimum possible and allow free use of the uninvolved fingers. Œdema of the fingers should be avoided, partly because of the probable increase in peri-articular adhesions when it is present, but also because of the restriction of movement.



Fig. 439. Fracture sites in the first metacarpal.
A. Oblique fracture of the shaft.
B. Transverse fracture at the base.
C. Stave fracture of the base.



Fig. 440 Greenstick fracture of the base of the first metacarpal.

cases should be put to bed for the first few days, to avoid œdema of the dependant hand, and to facilitate complete rest. (Fig. 436.)

Dislocation at the intercarpal and carpo-metacarpal joints is extremely rare. The path of separation and possible associated fractures is shown in Figs. 437, 438.

FURTHER READING

General

SCHNEK. "Die Verletzungen der Hand-wurzel," *Ergebn. d. Chir. u. Orthop.*, 1930, 23, 1. (The fullest German review of the subject, with copious references.)

SHORBE, H. S. "Carpo-metacarpal Dislocations," *J. Bone and Joint Surg.*, 1938, 20, 454. (One case and literature.)

RUSSELL, T. B. "Intercarpal Dislocations and Fracture Dislocations," *J. Bone and Joint Surg.*, 1949, 31A 524.

Navicular

OBLETZ and HALBSTEIN. "Non-union of Fractures of the Carpal Navicular," *J. Bone and Joint Surg.*, 1938, 20, 424.

MURRAY, G. "Bone Graft for Non-union of the Carpal Scaphoid," *Brit. J. Surg.*, 1934, 22, 63.

SOTO, HALL and HALSEMAN. "Treatment of Fractures of the Carpal Scaphoid," *J. Bone and Joint Surg.*, 1934, 16, 822.

DWYER, F. C. "Examination of the Carpal Scaphoid for Ununited Fracture," *J. Bone and Joint Surg.*, 1949, 31A, 572.

WAGNER, C. J. "Fractures of the Carpal Navicular," *J. Bone and Joint Surg.*, 1952, 34A, 774.

BARR, J. S. *et al.* "Fractures of the Carpal Navicular," *J. Bone and Joint Surg.*, 1953, 35A, 609.

Triquetrum

BONNIN, J. G., and GREENING, W. P. "Fractures of the Triquetrum," *Brit. J. Surg.*, 1944, 31, 278.

Hamate

MILCH. "Fractures of the Hamate," *J. Bone and Joint Surg.*, 1934, 16, 495.

GEIST. "Dislocation of the Hamate," *J. Bone and Joint Surg.*, 1939, 21, 215.

Lunate

ADAMS. "Displacement of the Carpal Semilumar Bone," *J. Bone and Joint Surg.*, 1925, 7, 665. (Review of 12 cases, with further references.)

FARR, C. L. "Dislocation of the Carpal Semilunar," *Ann. Surg.*, 1926, 54, 112.

WATSON JONES. "Carpal Semilunar Dislocations with Nerve Lesions," *Proc. Roy. Soc. Med.*, 1929, 22, 1071.

MONT, WILKIE and HARDING. "Isolated Fractures of the Carpal Semilunar and Kienbock's Disease," *Brit. J. Surg.*, 1931, 19, 577.

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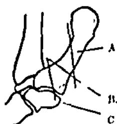


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FIG. 440. Greenstick fracture of the base of the first metacarpal.

Operative Fixation. The apparently absurd description of the phalanges as short " long bones " has been used for years, yet it is only recently that the same methods of treatment have been applied to both fingers and long bones. It is particularly in the fingers and thumb where comparatively small adhesions cause considerable disability that the advantages of operative fixation and early movements are likely to be of benefit, and striking improvement in results can be achieved by open operation in selected cases. Broadly speaking, injuries to the hands fall into two categories, whether bone is involved or not: those in which there is localised soft tissue trauma, best exemplified by a knife cut, and those in which there is crushing of soft tissue over a wide area, *e.g.*, in a compound fracture of a phalanx from a hammer blow. The result of the injury will depend on the degree of soft tissue damage, and the presence or absence of infection. By adequate surgery, skin grafting and chemotherapy the latter disaster should be avoided. No surgery can repair the damage of severe crushing, in which for example tendon and tendon sheath may be pulped together, but it can do much to minimise after effects. This is not the place to enlarge on the benefits of tendon suture with stainless steel wire, but the same material is a very useful agent for fixing small fractures, where screws are unavailable or unsuitable. Fractures in which metallic fixation is often desirable are :—

1. Fractures involving the interphalangeal joints, in which the fracture contributes to the instability of the joint, *e.g.*, the fracture of the posterior margin of the terminal phalanx with subluxation (mallet finger) (Fig. 469).
2. Comminuted phalangeal fractures (Fig. 467), particularly involving a joint.
3. Unstable oblique or spiral fractures of the phalanges.
4. Markedly unstable or displaced fractures of the metacarpals.

The opportunity for early fixation by the primary excision of compound wounds should not be neglected, as it is particularly in this type of case that gross displacement allows the inclusion of soft tissue in the fracture line, and is accompanied by soft tissue damage.

Post-operative care is extremely important, and movements of the affected finger should be encouraged as soon as possible when the tendons are intact. The limitation of movement of uninjured fingers should be minimal and these should be freely exercised. It is in the treatment of injuries to the hand that occupational therapy plays its most important role, while later on the sheltered workshop can be of great assistance in encouraging the patient to make the most of stiffened fingers.

Fractures of the Metacarpals

The first metacarpal. Types of fracture.

1. Transverse above the base. A. Impacted. B. Unimpacted.
2. Spiral or oblique of the shaft.
3. Oblique, involving the base. (True Bennett's fracture.)
4. Comminuted fractures.



FIG. 441. Fracture of the shaft of the first metacarpal.



FIG. 442. Same case showing the satisfactory result of treatment with a finger wire lying on the extensor aspect of the thumb.

In the first and second groups the proximal joint is not involved, and reduction and retention comparatively easy.

SYMPTOMS. In all cases these are similar, consisting of gross swelling of the thenar, bruising and pain. Crepitus can usually be easily detected, and false movement, particularly in Bennett's fractures, is obvious.

TRANSVERSE FRACTURES above the base of the metacarpal are commonly impacted. If this is so and there is little displacement the fracture is better left and the patient's attention concentrated upon active use. If there is marked displacement, or the fracture is loose, it must be held in position after reduction on a finger wire

splint of a similar type to that used for Bennett's fracture. The wire is run along the dorsum of the thumb, attached to the thumb by strapping, and then thumb and wire bent to the desired position. Immobilisation is maintained for two to three weeks, and removed as soon as active movements of the thumb can be carried out.

SPIRAL AND OBLIQUE FRACTURES of the shaft require some extension for their reduction. This is accomplished as in fractures of the other metacarpals by a wire finger splint incorporated in a forearm plaster. According to whether the angulation is volar or dorsal (Figs. 442, 450) the wire is placed on the flexor or extensor aspect of the thumb, which is attached to it by strapping. The position of the fragments is then controlled by bending the wire with the finger attached. Union is firm in three to four weeks.

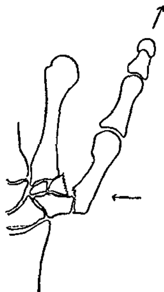


FIG. 443. Bennett's stave fracture of the thumb, showing the combination of fracture with dislocation and the direction of the forces necessary to maintain reduction.

BENNETT'S STAVE FRACTURE. In this case the fracture runs vertically from the joint surface to the medial border of the bone. It is due to violence applied in the line of the metacarpal, commonly from blows with the clenched fist, the base of the metacarpal being sheared off against the multangulum major (trapezium). The metacarpal in consequence slides up past the lateral aspect of the joint if the capsule is torn, and retention is difficult, particularly as the line of fracture is in the direction of pull of the muscles.

Clinically two types of stave fracture are met with .—

1. In which there is a small triangular chip fractured from the medial edge of the metacarpal, but there is no dislocation of the joint (see Fig. 444).

2. In which the fracture involves more of the base of the metacarpal, and dislocation consequently occurs (see Fig. 445).

In the first case there is no difficulty with retention, and reduction is equally easily accomplished by putting the thumb into full abduction.

In the second group of cases reduction is usually easy by traction and abduction of the thumb, for which a local anæsthetic is suitable, though often it can be done without. Retention is not easy and demands two factors, first, lateral pressure on the base of the metacarpal, and secondly, extension of the thumb. In certa



FIG. 444. Chip fracture of the base of the first metacarpal without dislocation.



FIG. 445. Chip fracture of the base of the first metacarpal, with dislocation of the carpo-metacarpal joint. Bennett's stave fracture.

lateral pressure alone, combined with full abduction of the thumb, suffices to maintain the fracture, which is accomplished as described below by strapping. Where this fails a more elaborate fixation is necessary, though in our experience the necessity for extension with a wire in the pulp of the finger never occurs.



FIG. 446. Method of strapping the thumb for injury at the metacarpal base. Site of application of the rubber pad



FIG. 447. Circular strapping, compressing the pad against the base of the thumb, of non-stretch strapping.



FIG. 448. Figure of eight strapping, abducting the thumb over the fulcrum provided by the compressed pad, of single stretch elastoplast.

Treatment. *First group.* A small square of plaster $\frac{3}{4}$ inch square and $\frac{1}{4}$ inch thick is made by winding some sticking plaster around a small piece of card, the last turns being reversed so that the sticky side is outwards, or a small square of sponge rubber may be used. This is placed over the base of the first metacarpal. A piece of ordinary strapping is then passed firmly over this and



FIG. ... wire finger ... reduction ... the small

around the hypothenar, so that the small pad is firmly pressed into the base of the thumb. By abducting the thumb over this it is used as a fulcrum to push the fractured surfaces together. Abduction is best produced by two or more turns of elastoplast passed over the thumb and around the wrist in a figure eight Control X-rays are then taken.

If satisfactory the dressing is left, and renewed in four days' time, and the position again controlled by X-rays. Unsatisfactory position demands remanipulation, and if this fails treatment as in the second group of cases.

Second group. A plaster is applied to the forearm to which is

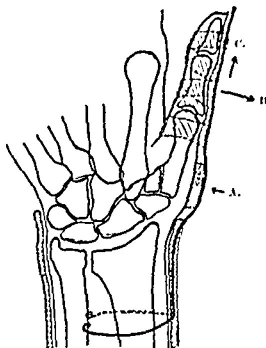


Fig. 450. Retention of a stave fracture with a finger wire incorporated in a forearm plaster.

A. Sponge rubber pad between the wire and the base of the thumb.
B. Thumb and wire are bent out in this direction to obtain traction in the direction C.



Fig. 451. A finger wire incorporated in a forearm plaster for retention of a reduced Bennett's fracture.



Fig. 452. The thumb strapped to the wire and extended.

attached a wire finger splint passing along the outer border of the thumb. This wire is covered by a layer of strapping, and at the base of the wire which corresponds to the base of the metacarpal a small square of rubber sponge 1 inch square and ½ inch thick is inserted between the wire and the metacarpal. The thumb is then abducted over this and attached to the splint by a few turns of strapping. Holding thumb and splint, both are bent so that the thumb is fully abducted over the small rubber pad. By this manœuvre both extension and lateral pressure on the thumb are obtained, and this usually suffices to retain the most difficult fractures. The strapping and rebending of the wire are repeated as often as necessary. Fixation must last three to four weeks. Care must be taken that the pressure of the sponge rubber does not produce a pressure sore.

Fractures of the other Metacarpals

May be :—

1. Fractures of the shaft. } {Due to either direct or indirect violence. } Transverse. Oblique or spiral.
2. Fractures of the neck.
3. Fractures of the base.

The fifth metacarpal is most commonly involved in direct violence Punch fractures most commonly affect the third metacarpal with the prominent knuckle, while multiple fractures are usually due to crushing injuries and are frequently compound.

Diagnosis. In addition to the usual features recession of one or other knuckle may be seen if there is shortening. In fractures without displacement pressure on the finger of the affected metacarpal or tapping the knuckle will produce pain. In oblique fractures telescoping may be noticed. Difficulties in diagnosis may arise in fine transverse fractures with no displacement which require careful scrutiny of the X-ray films to detect them. When this is being done care must be taken not to confuse the line of a nutrient artery with a fracture, as they are frequently very clear and suggestive.

Treatment. This depends on the degree of displacement and the freedom of mobility of the fingers. Restriction of movement will usually be found to be due to pain and this can be relieved by an injection of local anæsthetic. Minor degrees of shortening of the finger can be neglected, recession of the knuckle not being very important. In many cases the injection of novocaine suffices and the fixation of the finger should be avoided if possible. In other cases with pain and much bruising, and possibly fracture of other

metacarpals, it is best to immobilise the metacarpals in a plaster extending on the dorsum to the heads and well up to the distal palmar crease on the palm. This immobilisation of wrist and metacarpus results in a return in power to the affected fingers, which by gripping firmly over the end of the plaster exert a little traction on themselves. The active use of the fingers in such a plaster (Fig. 412) results in a rapid subsidence of the usual puffy swelling over the

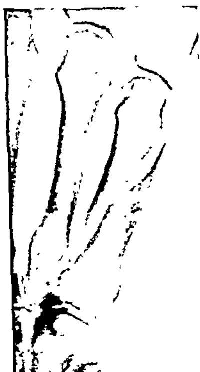


FIG. 453. An oblique fracture of the fifth metacarpal.



FIG. 454. A transverse fracture of the fourth and fifth metacarpal shafts.

dorsum of the hand, and the plaster can usually be removed in ten days to a fortnight.

In cases with displacement, or compound injuries, it is necessary to immobilise the finger after reduction. In open cases this is usually easy, but reduction may not be so easy to accomplish in closed cases by mere manipulation. The use of leverage by means of a thin Steinmann's pin inserted through the skin of the dorsum of the hand is not to be forgotten.

METHOD OF FIXATION BY FINGER WIRES. A volar plaster slab is applied to the forearm, extending from the metacarpal heads to just below the elbow, and so cut out in the palm that it affects flexion of the involved fingers only. On this is laid a wire finger splint, which is adjusted to be in line with and extend just beyond the pulp of the involved fingers. This is incorporated in the plaster

attached a wire finger splint passing along the outer border of the thumb. This wire is covered by a layer of strapping, and at the base of the wire which corresponds to the base of the metacarpal a small square of rubber sponge 1 inch square and $\frac{1}{2}$ inch thick is inserted between the wire and the metacarpal. The thumb is then abducted over this and attached to the splint by a few turns of strapping. Holding thumb and splint, both are bent so that the thumb is fully abducted over the small rubber pad. By this manœuvre both extension and lateral pressure on the thumb are obtained, and this usually suffices to retain the most difficult fractures. The strapping and rebending of the wire are repeated as often as necessary. Fixation must last three to four weeks. *Care must be taken that the pressure of the sponge rubber does not produce a pressure sore.*

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Treatment. This depends on the degree of displacement and the freedom of mobility of the fingers. Restriction of movement will usually be found to be due to pain and this can be relieved by an injection of local anæsthetic. Minor degrees of shortening of the finger can be neglected, recession of the knuckle not being very important. In many cases the injection of novocaine suffices and the fixation of the finger should be avoided if possible. In other cases with pain and much bruising, and possibly fracture of other

along which the finger is laid. The pressure tends to be a maximum under the head of the metacarpal, so a small square of felt is placed here between the wire and the bone. The finger is then strapped to the wire splint over this with narrow strapping. Extension is produced by bending the finger and splint together, the finger thus being compelled to follow a curve of larger diameter, and so pulling on the metacarpal head. About every four days the strapping must be renewed and the splint rebent. X-ray control of the fracture is simple. Immobilisation is maintained for three weeks, the other fingers being carefully exercised. After removal of the splint return of function is usually rapid. It is important that the finger should be held in flexion as the lateral ligaments of the interphalangeal joints are then held stretched and unable to shorten, a potent cause of stiff fingers (Fig. 457).



FIG. 458. Forearm plaster carrying a finger wire for extension of a fracture of the proximal phalanx of the middle finger. Note felt pad under the head of the metacarpal. Wire is shown extending unnecessarily far beyond the end of the finger. Usually it need only be the length of the finger, which is strapped to it, and both wire and finger flexed together.

FRACTURES OF THE METACARPAL BASES. There is as a rule no displacement, and to relieve pain all that is necessary is a plaster to the level of the metacarpal heads. This is maintained for a fortnight to three weeks, and early finger movements commenced, as in all other cases.

FRACTURES OF THE NECK OF THE METACARPAL. These may give rise to a little difficulty as there is a tendency for the head to bow forwards, especially if the fracture is treated with a tennis ball or bandage clasped in the palm. The prominent head then receives all the pressure in gripping, and in time becomes very painful. For this reason the correction of the deformity is important. It can only be satisfactorily achieved by using the proximal phalanx as a bar to push the flexed head back. Once reduced the cases fall into two classes, those which will remain reduced with no further immobilisation, and those which require some retention. Retention may be of a temporary nature, consisting of strapping passed over the knuckle from the dorsum of the hand and continued over the finger which is flexed into the palm with the distal interphalangeal joint straight,



FIG. 455. The same case under treatment with two wire finger splints incorporated in a light forearm plaster.

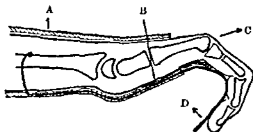


FIG. 456. Retention of a phalangeal fracture with a finger wire incorporated in a forearm plaster The same principles are employed for metacarpal fractures.

A. Plaster. B Finger wire. C. Resultant direction of pull if finger and wire are strongly bent in the direction D.

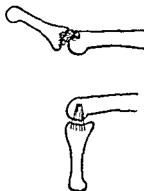


FIG. 457. Illustrating the effect of extension and flexion on the lateral ligaments of the interphalangeal joints. If the finger is held flexed the ligament is stretched, and so cannot shorten and produce a stiff finger joint.

by passing a few circular turns of plaster over it, these turns extending from the elbow to the wrist if a single metacarpal is affected, but over the dorsum of the wrist if two or more are broken. The finger wire is then covered with strapping to make a flat surface

of the finger and should be removed at the earliest opportunity, about the tenth day.

Fractures of the Phalanges

Surgical Anatomy

Like the metacarpals the proximal and middle phalanges are short "long" bones, and suffer similar fractures. The terminal phalanx, however, differs in construction, having a splayed out head of cancellous bone. It is the most liable to crushing injuries.



FIG. 462 An oblique fracture of the proximal phalanx of the thumb involving the joint.

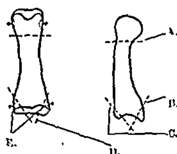


FIG. 463. Fracture sites in the phalanges.
A. At the neck.
B. Anterior marginal fracture of the base.
C. Posterior marginal fracture of the base.
D. Lateral marginal fractures.
E. Sites of ligament traction fractures.



FIG. 464. A transverse fracture of the proximal phalanx of the thumb.

Ossification. A secondary centre for the proximal ends of the bones appears at the end of the second year and unites about eighteen to twenty years.

Types of Fracture

Shaft. Oblique, transverse and comminuted. Epiphysis rarely separated.

Ends. 1. Anterior, posterior, and lateral marginal fractures involving the joint.

2. Ligament traction fractures due to forced abduction or adduction of the finger.

Any of these fractures may be associated with a dislocation

and then over the wrist. A circular layer around the palm maintains the flexion at the proximal joint. This method is most satisfactory in the case of the fifth metacarpal, which is the most commonly

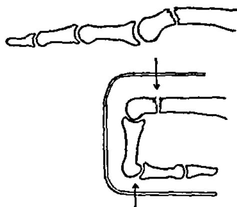


Fig 459. Reduction and retention of fractures of the neck of the fifth metacarpal. The typical displacement is shown above. Below the method of retention with a dorsal finger wire bent around the finger, and pressing on the head of the proximal phalanx. The finger wire is steadied in a forearm plaster.



Fig. 460. Fracture of the necks of the fourth and fifth metacarpals.

injured A more durable method of fixation is provided by running a finger wire down the back of the finger, after incorporating it in plaster, as shown in Fig. 458. It is a more certain method of preventing a recurrence of deformity, but is apt to produce stiffness



Fig. 461. Retraction of the fourth knuckle of the left hand after fracture of the metacarpal.

two days by a padded finger splint of the type shown in Fig. 48, and early movements encouraged.

Shortening is important to avoid, but is easy to control by the above method. Angulation is similarly easy to control but rotation is

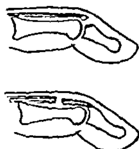


Fig. 468. Mallet finger. Above due to fracture of the insertion of the extensor expansion (posterior marginal fracture). Below due to rupture or division of the extensor expansion.



Fig. 469. A posterior marginal fracture of the base of the terminal phalanx.



Fig 470 The position of the finger in a mallet finger plaster.



Fig. 471. The patient maintaining the position as the plaster sets.

apt to be overlooked. If the finger has united with a rotation deformity it may appear quite straight when extended, but on flexion the terminal phalanx or middle phalanx will slew to one or other side, which may be a very severe disability in a skilled worker.

Fractures of the phalangeal ends. Abduction and adduction strains may result in a ligament traction fracture, the collateral

of the interphalangeal joint and many may be best treated by fixation with a small screw or stitch of stainless steel wire.

Fractures of the shaft. These are easily reduced under general



FIG. 465 A fracture separation of the epiphysis at the base of the proximal phalanx of the fourth finger.

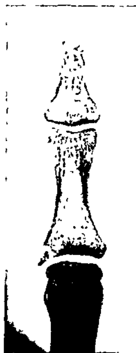


FIG. 466. A lateral marginal fracture of the base of the proximal phalanx of the thumb.

or local anæsthesia and are best fixed on a finger wire splint similar to that used for fractures of the metacarpals Being only a skeleton splint it is very adaptable and equally useful in the presence of lacerations, which it is desired to leave open to the air. The finger should be kept flexed to avoid subsequent stiffness. Union occurs in three to four weeks, when the splint is removed and exercises encouraged (Fig. 456).



FIG. 467. A P. view of a compound comminuted fracture of the base of the proximal phalanx of the thumb *b.* Lateral view of the same case. *c* and *d.* Corresponding views of same case after open operative reduction and fixation of the fracture with stainless steel wire.

It must be remembered that quite a large number of phalangeal fractures are stable, often in spite of being comminuted, and not appearing so in the radiograph. Other phalangeal fractures remain stable after reduction, and in all these cases the finger should be merely protected for the first

two days by a padded finger splint of the type shown in Fig. 48, and early movements encouraged.

Shortening is important to avoid, but is easy to control by the above method. Angulation is similarly easy to control but rotation is

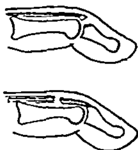


Fig. 468. Mallet finger. Above due to fracture of the insertion of the extensor expansion (posterior marginal fracture). Below due to rupture or division of the extensor expansion.



Fig. 469. A posterior marginal fracture of the base of the terminal phalanx.



Fig. 470. The position of the finger in a mallet finger plaster.



Fig. 471. The patient maintaining the position as the plaster sets.

apt to be overlooked. If the finger has united with a rotation deformity it may appear quite straight when extended, but on flexion the terminal phalanx or middle phalanx will slew to one or other side, which may be a very severe disability in a skilled worker.

Fractures of the phalangeal ends. Abduction and adduction strains may result in a ligament traction fracture, the collateral

ligaments of the joint pulling a small portion of bone of the base away with their attachment, or occasionally fracturing the base into the joint. Blows on the flexed finger may result in anterior or posterior marginal fractures, which may be associated with dislocations, the anterior fracture tending to allow posterior dislocation and *vice versâ*. In most cases the displacement is small, and all that is needed is adequate rest for three weeks with the finger flexed, which is secured by a wire finger splint set in plaster as outlined. Where there is displacement traction is applied by bending the wire with the finger attached, and this reduces and fixes the fracture. Owing to the involvement of the joint stiffness is liable to be more marked than in fractures not involving it Crush fractures with considerable joint destruction can be very crippling owing partly to joint damage and partly to fibrosis and adhesions around the tendons, and in many of these cases early complete and accurate operative reduction is necessary (Fig. 467).

Fractures of the terminal phalanx. May be :—

1. Longitudinal. } Due to crushing injuries.
2. Transverse. }
3. Chip fractures. Anterior. Rare, due to hyperflexion.
   Posterior. Due to a blow. Mallet finger.
   Lateral. Due to abduction and adduction.

All these fractures may be associated with lacerated and bruised pulps, and are frequently compound. Such fractures are carefully cleaned up under block-finger anæsthesia and sutured. If the nail is damaged it is better removed, as it relieves pressure below it, an important cause of pain, and it allows the wound to dry up Further, in any case with displacement of the nail the fracture is frequently compound into the nail bed and its removal provides opportunity for suture of a potentially infected area No harm has ever been done by removing a nail carefully ; much has been caused by leaving it in place. All such fractures must be immobilised on a finger splint *at once, and maintained at rest until healing has commenced.* In cases in which there is no great damage to soft parts a collodion splint made of several turns of gauze soaked in collodion, or a splint of several turns of strapping may provide sufficient protection and rest. They are renewed till the finger is free from pain.

Compound fractures of the terminal phalanx are frequently accompanied by partial amputation of the pulp Where the bone is exposed a Thiersch graft will not take and some form of flap, *e.g.*, from the palm or the thigh, must be used to cover it, and to avoid shortening the digit The value of this procedure which takes time must depend on the value of the digit, and is always necessary for the thumb where it is essential to preserve its length. Where the pulp

tissue is only sliced across it is sufficient to use a Thiersch graft, or pinch graft (see Fig. 65).

Mallet finger more commonly occurs from rupture of the extensor tendon than from fracture at its insertion. Three clinical varieties can be distinguished.

1. Due to rupture of the extensor tendon. Best treated in young people by tendon suture by the Bunnell technique, with the strain relieving suture running through the pulp of the finger, and tied over a button on the end, maintaining hyper-extension. Alternatively a mallet finger plaster (Fig. 471) may be applied for four weeks. Full extension is scarcely ever obtained by this method, but the resultant drop is little disability.

2. Due to fracture of the posterior margin involving the insertion of the extensor tendon. (a) Without subluxation. (b) With volar subluxation of the terminal phalanx. The prognosis in these cases for a good functional result in spite of the fracture into the joint is better than for tendon ruptures provided complete reduction can be obtained. This should be attempted by a mallet finger plaster in the first instance. If the displacement or the subluxation persists, the fragments should be perfectly reduced by open operation through an incision, and the fragment retained in position by a suture of stainless steel wire, passed around or through the bone.

Anterior chip fractures of the base require rest in a slightly flexed plaster finger splint. One important point in diagnosis is that there is frequently a small sesamoid in the tendon of the flexor profundus at its insertion and it must not be mistaken for a fracture. It is regular in outline, often rounded, and may be seen in other fingers or the same finger of the opposite hand. When there is an accompanying posterior subluxation this must be carefully reduced employing open operation and suture when necessary.



Fig. 471a. Fracture of a sesamoid bone of the thumb. There is also a sesamoid bone at the insertion of flexor pollicis longus into the base of the distal phalanx. This is commonly present and may be mistaken for a fracture.

Lateral marginal fractures of the base can be treated in a plaster finger splint in slight flexion for two to three weeks, after which movement is encouraged. Great care must be taken in these cases to make certain that the commonly associated interphalangeal subluxation is fully reduced.

Sesamoid Fractures. These are more uncommon in the hand than in the foot (see p. 645). There are no congenital abnormalities of the hand sesamoids to confuse diagnosis. The sesamoids in the flexor tendons of fingers are inconstant in appearance, and may be mistaken for volar maginal fractures by the unsuspecting. Fractures of the thumb sesamoids may occur as the result of compression (Fig. 471a). Gentle supporting pressure till swelling has subsided and early active exercises after this is all that is required in the way of treatment.

FURTHER READING

Metacarpals

JAHSS, S. A. "Fractures of the Metacarpals," *J. Bone and Joint Surg.*, 1938, 20, 178.

RIDER, D. L. "Fractures of the Metacarpals, Metatarsals and Phalanges," *Am. J. Surg.*, 1937, 38, 549.

ROBERTS, N. "Fractures of the Phalanges of the Hand, and of the Metacarpals," *Proc. Roy. Soc. Med.*, 1938, 31, 793. (Sound review including statistics.)

MCNEALY and LICHTENSTEIN. "Bennett's Fracture and other Fractures of the First Metacarpal," *Surg. Gynæ. and Obstets.*, 1933, 56, 197.

Phalanges

SMITH, F. L. and RIDER, L. "A Study of the Healing of 100 Consecutive Phalangeal Fractures," *J. Bone and Joint Surg.*, 1935, 17, 91.

SMILLIE. "Mallet Finger," *Brit. J. Surg.*, 1936, 24, 439.

CHAPTER XXVI

FRACTURES OF THE PELVIS, SACRUM AND COCCYX

Development. The three bones of the os innominatum commence ossification from primary centres appearing in the ilium in the second month, the ischium in the third, and the pubis in the fourth month. Ossification continues slowly, and at the tenth year a variable number of centres for the acetabulum appear. These occasionally fuse to form the os acetabuli. At sixteen to eighteen years they fuse with the other centres, completely ossifying the acetabulum. In the cartilaginous border of the bone a variable number of secondary centres appear at puberty, as follows :—

1. For the anterior superior iliac spine and anterior part of the iliac crest.
2. For the posterior superior iliac spine and the posterior half of the iliac crest.
3. For the anterior inferior iliac spine.
4. For the ischial spine.
5. For the surface of the ischial tuberosity.
6. For the angle of the symphysis.
7. An incessant centre for the pubic spine.

These fuse with the main centres about twenty-one years.

Surgical anatomy. The bone consists of two parts, meeting roughly at right angles, the ilium above, forming the wing of the false pelvis, and the ischium and pubis below forming the lateral wall of the true pelvis. The transition from one plane to another is sudden externally, but gradual internally, where the angle is strengthened by the ilio-pectineal bar. The pelvis is inclined so that the pelvic brim forms an angle of 60° with the horizontal. [illegible]
the two [illegible]
mitted [illegible]
and so tends to open the two halves of the pelvis and to put traction on the pubic symphysis. In sitting down the weight is transmitted by the ischial tuberosities, which lie medial to the line of the sacro-iliac joint, and so the tendency is to compress the pubis. The curves of the pelvis adapt it as an elastic base for transmitting the weight of the spine to the legs or the ischial tuberosities, while the sacrum is slung between the two halves of the pelvis as the centre piece of a cantilever.

Of the soft tissues in contact with the bony pelvis, the rectum, urethra, and, in the female, the vagina, are the most important, as all may be damaged indirectly by the entry of bony spicules, or more commonly directly by the injury, with consequent risk of sepsis. In the female the urethra is well protected, but in the male, on account of the close relationship of the urethra to the pubic arch, and its comparative fixity, it is liable to injury, particularly in falls astride. The rectum is in relationship to the anterior surface of the last two and a half pieces of the sacrum and the coccyx. It is rarely injured except by perforating injuries and gunshot wounds. The iliac vessels and the sciatic nerve, though closely related to the bone, are rarely injured, though the sciatic nerve may be involved in lesions in the sacro-iliac region.

The mechanical construction of the pelvis presents a series of weak spots through which fracture is most likely to occur, either alone, or more commonly in combination with a second fracture through another weak spot. The weak spots are :—

Anteriorly. The pubic symphysis.
The ischio-pubic rami.
Centrally. The acetabular floor.
Posteriorly. The sacro-iliac joint } or a mixed lesion involving both.
The ala of the ilium }
The lateral mass of the sacrum where weakened by the formaniæ.

FRACTURES OF THE PELVIS

Mechanism. Fractures of the pelvis occur through :—

1. Direct violence to the iliac crest.
2. Crushing and "run over" injuries.
3. Muscular violence avulsing the origins of muscles.
4. Leverage imparted to the hemi-pelvis (os innominatum) by forced movements of the leg.
   (*a*) Abduction. Opens pubic symphysis.
   (*b*) Hyper-extension. Twists os innominatum off the sacro-iliac joint, and produces alterations in level of the pubis.
5. Direct pressure imparted to the acetabulum by the femoral head, *e.g.*, in dash board injuries.



Fig. 472. The mechanism of double pelvic fracture by forced hyper-extension of the leg, which rotates off one half of the pelvis

Odd combinations of these injuries may occur and there are thus a great variety of fractures possible, which can only be classified with difficulty. The pelvis is best regarded as a rigid ring with three elastic insets, the pubis anteriorly and the two sacro-iliac joints posteriorly. There is a weak area anteriorly on either side of the symphysis, through the ischio-pubic rami. Injuries which result from crushing the ring cannot produce a deformity in one part without a corresponding deformity in another part. If a "single" fracture is seen, it is most probable that the secondary deformity has occurred through a sacro-iliac joint or the symphysis. Only in the region of the ala of the ilium is the bone sufficiently rigid and brittle for a fissure fracture to occur as the result of a blow with no secondary disturbances of the ring, *i.e.*, a true *single fracture*. The sites of ruptures can be classified on their position in the ring, thus :—

Anterior. The pubic symphysis and the bone on either side of it anterior to the acetabulum.
Central. The acetabular region.
Posterior. The ilium and the sacro-iliac joint and the bone on either side of it.

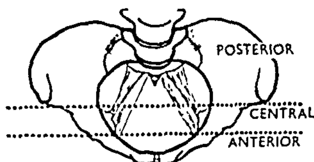


FIG. 473. The sites of fracture of the pelvic ring.

In practice central fractures tend to occur alone without involving the anterior and posterior portions of the ring, though rarely the two quarters of the ring on either side of the acetabulum are pushed in and a fracture, joint separation, or joint fracture separation occurs in either or both the anterior or posterior portions of the ring.

Double fractures may occur in the anterior portion of the ring, through the ischio-pubic rami on either side of the pubis, or through one side and the pubis. Unilateral fractures of the anterior portion are usually accompanied by a hidden (sacro-iliac strain) or revealed lesion in the posterior portion of the ring, while double lesions anteriorly may have a single accompanying lesion posteriorly (triple fractures) or a double lesion (quadruple fracture).

A complete classification would thus be :—

A. " Single " ruptures of the pelvic ring.
   1. Separation or fracture-separation at the pubis symphysis.
   2. Separation or fracture-separation at the sacro-iliac joint.
   3 Fractures of the ischio-pubic rami.
   4. Fissure fractures through the ilium, or acetabular floor.

B. Double ruptures of the pelvic ring.
   1. Fracture of both ischio-pubic rami, or fracture of one ischio-pubic region and separation at the symphysis
   2. Fracture in the anterior portion of the ring, and fracture or fracture-separation of the sacro-iliac joint, *e.g.*, the double vertical fracture of Malgaigne (Fig. 477)
   3. Fractures through the acetabular floor accompanied by displacement of one quarter of the ring.

C. Triple ruptures of the pelvic ring.
   1. Double fracture anteriorly and a single lesion posteriorly.
   2 Fracture through the acetabular floor and displacement of both quarters of the pelvis on either side of it.
   3. Diastasis of the pubic symphysis.

D Quadruple fractures of the pelvic ring.
   A double fracture anteriorly and a lesion through or near both sacro-iliac joints posteriorly

E. Fractures of the acetabular or central region without displacement.
   1. Fracture of the rim (Associated with posterior dislocation of the hip)
   2. Fracture of the acetabular floor. (Associated with central dislocation of the hip)

F Fractures of the processes of the pelvis.
   1 Fracture of the ala of the ilium.
   2 Fractures of a single ischio-pubic ramus. (Direct violence.)
   3 Fractures of the anterior superior iliac spine. (Due to the pull of the abdominal muscles)

The mechanical construction of the pelvis presents a series of weak spots through which fracture is most likely to occur, either alone, or more commonly in combination with a second fracture through another weak spot. The weak spots are :—

Anteriorly. The pubic symphysis.
The ischio-pubic rami.
Centrally. The acetabular floor.
Posteriorly. The sacro-iliac joint, The ala of the ilium } or a mixed lesion involving both.
The lateral mass of the sacrum where weakened by the formanie.

FRACTURES OF THE PELVIS

Mechanism. Fractures of the pelvis occur through :—

1. *Direct violence to the iliac crest.*
2. Crushing and "run over" injuries.
3. Muscular violence avulsing the origins of muscles.
4. Leverage imparted to the hemi-pelvis (os innominatum) by forced movements of the leg.
   (a) Abduction. Opens pubic symphysis.
   (b) Hyper-extension. Twists os innominatum off the sacro-iliac joint, and produces alterations in level of the pubis.
5. Direct pressure imparted to the acetabulum by the femoral head, *e.g.*, in dash board injuries.



FIG. 472. The mechanism of double pelvic fracture by forced hyper-extension of the leg, which rotates off one half of the pelvis

Odd combinations of these injuries may occur and there are thus a great variety of fractures possible, which can only be classified with difficulty. The pelvis is best regarded as a rigid ring with *three elastic insets*, the pubis anteriorly and the two sacro-iliac joints posteriorly. There is a weak area anteriorly on either side of the symphysis, through the ischio-pubic rami. Injuries which result from crushing the ring cannot produce a deformity in one part without a corresponding deformity in another part. If a "single" fracture is seen, it is most probable that the secondary deformity has occurred through a sacro-iliac joint or the symphysis. Only in the region of the ala of the ilium is the bone sufficiently rigid and brittle for a fissure fracture to occur as the result of a blow with no secondary disturbances of the ring, *i e.*, a true *single* fracture. The sites of ruptures can be classified on their position in the ring, thus :—

Anterior. The pubic symphysis and the bone on either side of it anterior to the acetabulum.
Central. The acetabular region.
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may be fractured, or the attachments of the os innominatum to the sacrum may be strong enough to separate the lateral mass of the sacrum from the body of the bone.

The degree of displacement present will vary with the type of fracture, and whether or not the force has continued to act after the fracture has occurred.

Examination and diagnosis of pelvic fractures. In severe pelvic fractures the satisfactory examination of the case may be prevented by shock or associated injuries. If the patient is conscious he will complain of local pain, and of pain on moving the leg on the affected side. Where the ring is completely broken he may complain of a sensation of falling apart. Hæmatomas should be searched for, particularly the tell-tale one in the perineum which indicates a probable rupture of the urethra. Palpation of the pubic and ischial rami is easy and should not be neglected. Irregularity in the line of the crest of the ilium may be appreciated with the fingers without turning the patient. In cases where there is suspicion of fracture the pelvis may be sprung by pressing firmly down and out on the anterior superior iliac spines (Fig. 474). The patient will complain of pain over the fracture site if the pelvic ring is broken. Separation or an alteration in the levels at the pubic symphysis may be felt. Finally, the examination is not complete without a search for damage to the urethra or bladder, especially in the presence of any of the four classical signs, hæmorrhage from the urethra, retention of urine, perineal bruising, and extravasation of urine; and in some cases a rectal examination. A neurological examination should be made in all cases in which the sacrum is fractured.



FIG. 474. Testing for pain in doubtful fracture of the pelvis by pressure on both anterior superior iliac spines.

Single Fractures of the Pelvic Ring

It is to be remembered that though a single fracture may be seen on the film, there is commonly an associated subluxation with minor fractures around the sacro-iliac joint, which cannot be seen. The most common single fracture is through the two weak points

4. Avulsion fracture of the anterior inferior iliac spine due to the pull of the rectus femoris.
5. Avulsion fractures of the tuberosity of the ischium, due to the pull of the hamstrings.
6. Fractures of the sacrum and coccyx below the ring.
7. Avulsion fractures of the ischial spine or the lateral margin of the sacrum, due to the pull of the sacro-spinous and sacro-tuberous ligaments during pelvic distortion.

Introductory. Clinically fractures of the pelvis fall into two groups, the very serious and the comparatively innocuous. These are usually those with displacement and those without displacement. The complications encountered in the severe injuries are

1. Increased and severe shock.
2. Retroperitoneal hæmorrhage.
3. Abdominal injury.
4. Injury to the bladder and urethra.
5. Injury to the rectum.

Apart from these complications there is little to be feared. The displacement is, as a rule, small, owing to the fixation of the bone by muscular and ligamentous attachments, and the chief concern is to make the patient comfortable while union is occurring.

Acetabular fractures may be produced by falls on the lateral aspect of the great trochanter, or falls in which one leg in the extended position receives the full weight of the body. If the head is not driven centrally one half of the pelvis may be dislocated, but more commonly the double vertical fracture of Malgaigne (Fig. 477) results. This particular lesion may be produced by lateral crushing. The arch is first broken anteriorly, and the continuation of the force breaks the arch posteriorly, or separates the sacro-iliac joint. Perhaps more common than separation is a subluxation of the sacro-iliac joint, and associated with this are small fractures of the anterior surface of the ilium at the joint margin. These cannot be seen on X-ray films, but are consistently found at post mortems on patients with severe pelvic injuries. Crushes in which the force is applied in an antero-posterior direction tend to fracture the rami on both sides and depress the pubic symphysis (Fig. 478).

The most common cause of pelvic injuries is, however, the leverage applied to one half of the pelvis through the leg. Hyper-abduction, or more commonly hyper-extension, tends to twist off the affected side of the pelvis. The line of separation has many paths to choose from. Anteriorly it may pass through the pubic symphysis, the weak area in the two rami, or through the area just anterior to the acetabulum. Posteriorly the choice is even more varied. Separation may occur at the sacro-iliac joint, or partly through this joint and partly through the ala of the ilium, the ilium

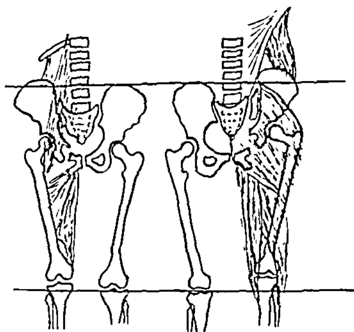


Fig. 477. The double vertical fracture of Malgaigne, showing how the displacement is produced by the contraction of the pelvi-femoral and vertebro-femoral muscles.



Fig. 478 Fracture of both ischio-pubic rami, together with an impacted fracture to the left of the pubic symphysis and a crush fracture of the right side of the sacrum involving the sacro-iliac joint.

Fig. 475 Fracture of the left ala of the ilium involving the sacro-iliac joint together with dislocation of the pubic symphysis, and upward displacement of the left half of the pelvis (Compare with Fig. 476.)

Fig. 476. Same case under treatment showing the reduction of the displacement by traction, first skeletal and then skin traction.

displacement is as a rule small, and rest in bed, as previously described, is the correct treatment.

Gross sacro-iliac separation is very rare unless associated with fractures elsewhere. The minor degrees of sacro-iliac separation associated with marginal chip fractures, which may be overlooked in the X-ray, may be the cause of persistent pain if the patient is not adequately rested after the accident.

Double Fractures of the Pelvic Ring

The classical fracture of Malgaigne is a very severe injury which brings a very seriously shocked patient into hospital. In this lesion the fracture is through the weak areas of the rami anteriorly, and through the sacro-iliac joint or just immediately lateral to it posteriorly, on the same side. The displacing force, together with the pull of the pelvi-femoral and vertebro-femoral muscles results in an upward displacement of the whole half of the pelvis, often associated with grave internal injuries. In some cases the fracture passes through the sacro-iliac region of the opposite side, in which case there is no displacement. Injury without displacement is due to lateral crushing injuries, while that with displacement is due to falls on the extended leg or on one half of the buttocks, and there may, in addition to the signs outlined above, be shortening of one leg.

In the rarer type of double fracture due to antero-posterior compression the pubic rami of both sides fracture at their weak spots, and the symphysis is depressed. This fracture is important, as under the usual treatment with a tight binder or a sling the two halves of the pelvis may be approximated, and the pelvic inlet and outlet considerably narrowed, which in the female may lead to difficult labour. Such cases should be nursed flat on a divided mattress (Fig. 478) and often without a pelvic sling.

Complicated multiple fractures must be treated on their merits according to the fractures present. There are usually more important injuries present, such as rupture of the bladder, which demand urgent treatment. For the patient's comfort treatment as for double fractures of the pelvis should be carried out if possible.

Treatment of double fractures. (Uncomplicated.) Treatment is directed to making the necessary movements of the patient as comfortable as possible and, by adequate support, allowing as much exercise to the rest of the body as is compatible with the patient's condition In cases with displacement of the fractured pelvis this must be combined with traction to maintain reduction.

Reduction of the displacement. This may be accomplished rapidly under spinal or general anæsthesia by lying the patient on

on the pelvic ring, where the obturator notch grooves the upper ramus of the pubis, and where the lower rami of ischium and pubis meet. The displacement is variable and usually small. The ends of the bones are finely spiculated and interlock. As a rule there are no complications and the treatment consists of rest in bed for a short time. Complete bed rest will be needed till pain subsides.



Fig. 479. Fracture of the pelvis associated with fracture of the sacrum. The pelvis and ischium are fractured anteriorly. The lateral mass of the sacrum is fractured and compressed, with loss of the sacral pattern, and the whole innominate bone is displaced upwards. There is a fracture of the transverse process of the fifth lumbar vertebra. Note the defect in the lateral margin of the sacrum below the pelvic brim. Features of root damage to S. 1 and 2 accompanied this lesion.

Graduated bed exercises are then commenced, and according to the patient's freedom from pain and development of muscular control he is allowed to sit out, start standing and walking. Depending on his age, general condition and the severity of the fracture, he should be about and active at the end of three to four weeks and fully restored to health a month later.

Less commonly the fracture occurs just lateral to the pubic symphysis, leaving the circle of bone around the obturator foramen complete, or the pubic symphysis may be dislocated with a subluxation of one or other sacro-iliac joint associated. The

the sound side with the sound leg held firm by being bandaged to a straight splint, and combining a certain degree of abduction with traction on the affected limb. (Attempts have been made to apply a plaster spica to maintain reduction after this has been done (Watson-Jones), but in our experience this is neither satisfactory nor comfortable for the patient.) In practice the slow reduction of the displacement by traction on a Kirschner wire or Steinmann's pin in the lower end of the femur is more readily combined with the treatment of shock and after-treatment of the patient, and is recommended.



FIG. 480 The reduction of a displaced half of a fractured pelvis by

A fracture bed is prepared with two overhead bars lying parallel to the sides of the body. Two Braun's splints are bandaged in the usual way and placed on the bed, and a pelvic sling, consisting of a canvas sheet 30 × 10 inches attached to wooden rods at each end, is laid at the upper end of the

two sides. If there is a tendency for the pubic symphysis to gape the cords are crossed and pass to the pulleys of the opposite side. After passing a wire or pin through the lower end of femur on the affected side, skin extension is applied to both legs, and 10 lbs. extension attached to each. The pin or wire is placed in the lower end of the femur, as the force necessary for reduction may amount to 40 lbs., and it is unwise for such a force to act through the

knee. A pull of 20 lbs. is used to commence with. This necessitates elevation of the foot of the bed, and if the weight has to be increased to 40 lbs., blocks of 18 to 20 inches must be used to get adequate counter-extension from the body weight. With such a weight on one leg it is necessary to increase the weight on the other to prevent twisting of the pelvis, and this may necessitate a wire in the tibial tuberosity of the sound leg. *If the weights have been* built up to 40 to 50 lbs. and the extension has acted for three days without producing reduction, then manipulation under a general anæsthetic, as previously described, will result in reduction and the patient can be put back to bed with extension to maintain it. Foot drop is prevented by one of the

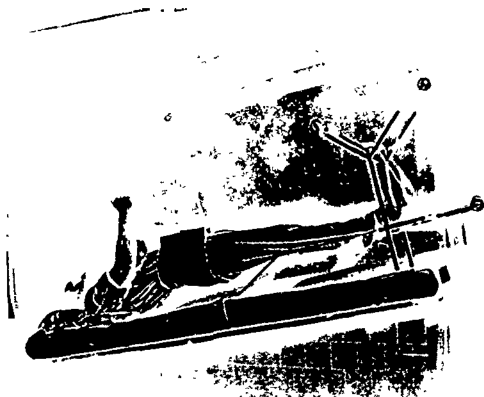


FIG. 481. Patient with a fractured pelvis, arranged with a crossed sling counterpoised with weights, and both legs resting on Braun's splints. Patient raising himself for the use of the bed pan.

methods shown in Figs. 533, 539. A
raise himself for the use of the bed pa
with the sling prevents the developme
carried out to a fairly active degree.

Union cannot be expected to be sound for weeks. The pin is removed at the third week, and the splints and skin traction as soon as the patient is able to dispense with them. The patient should be up and about by the eighth week.

Fractures with no displacement. Where there is no displacement the arrangement of the patient is the same, but the extension through the femur is omitted. That on the legs is used to steady the patient,

and relieve the pressure on the sacrum. Exercises in such cases can be begun earlier, and be more active. The period of immobilisation likewise can be reduced, according to the progress seen in radiographs. Usually at the end of four weeks the patient can be nursed without apparatus in a bed with a divided mattress, and at the end of a further four to six weeks can begin to walk. Little disability results from these cases in the absence of complications.

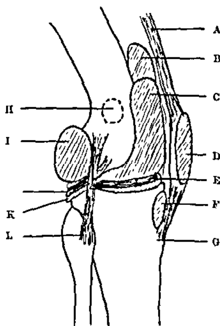


Fig 482. Diagram illustrating the correct site for the introduction of a Kirschner wire (or Steinmann's pin) into the lower end of the femur. The site lies ½ inch *anterior to and ½ inch above the* adductor tubercle. A. Quadriceps tendon B. Suprapatella bursa C. The synovial sac of the knee. D The patella. E. The meniscus F Infrapatella bursa. G Tibial tuberosity. H. The ideal area for insertion of the wire. I Semi-membranosus bursa. J Tendon of popliteus K The bursa around the popliteus tendon. L The fibula collateral ligament of the knee.

Fractures of the Acetabulum

These may be : (1) Fractures of the rim, associated with posterior dislocations, and (2) fractures of the acetabular floor associated with central dislocations (Fig. 483). The latter are usually due to falls on the lateral aspect of the great trochanter. More commonly an abduction fracture of the neck of the femur results, but where this does not occur the head may be driven into the floor of the acetabulum sufficiently hard to produce a fracture. In the majority of cases the head is not driven completely through into the pelvis. Less commonly the lesion results from a fall on the extended leg.

1. *Fractures of the acetabular rim* are reduced when the dislocation commonly associated with them is reduced, but occasionally the fragment may get into the hip joint preventing full reduction. Such rare cases require open operation. The two common varieties are dependent on the size of the fragment.

1. Small. At least partly reduced when the dislocation is reduced. These are left as they are not likely to cause trouble. The hip is stable after reduction.

2. Large The damage to the posterior rim is sufficient to make the hip joint unstable, and the fragment remains partly displaced after reduction associated with a partial subluxation of the hip. These cases demand open operation on the hip through a posterior

approach and the nailing or screwing of the fragment into position. Confusion with the occasionally present os marginale is to be avoided by careful examination of the X-ray.

2. *Fractures of the acetabular floor.* In the less severe cases the signs and symptoms resemble those of fracture of the neck of the femur. Where there is a central dislocation the depression of the trochanter can be noted and the head of the femur may be palpable per rectum.



Fig. 483. Central dislocation of the head of the femur with fracture of the acetabular floor.

The treatment is similar to that of a complete fracture of the pelvis with displacement. The amount of extension necessary varies with the amount of displacement of the head of the femur and may have to be raised to 30 to 40 lbs. to obtain reduction. It is helpful in many cases to supplement this with a direct lateral pull from a Kirschner wire passed vertically through the great trochanter and to which is attached a 10-lb. pull over a pulley on the side of the bed. If this fails manipulation must be tried. When reduced the extension can be reduced to 10 to 14 lbs. The displaced fragments of the floor follow the head to a variable degree. Such traction is maintained for six weeks and then reduced to 10 lbs. on skin traction, and the patient encouraged to exercise. At the end of twelve weeks the patient is allowed about on a walking calliper. This is abandoned in a further three to six months. In spite of the seriousness of the lesion the results are better than might be expected, as the roof of the acetabulum frequently escapes serious damage. A hip with good



Fig. 484. Separation of the pubic symphysis with wide opening of the sacro-iliac joints.



Fig. 485. Reduction of separation by a simple pelvic sling with crossed traction.

and relieve the pressure on the sacrum. *Exercises in such cases can* be begun earlier, and be more active. The period of immobilisation likewise can be reduced, according to the progress seen in radiographs. Usually at the end of four weeks the patient can be nursed without apparatus in a bed with a divided mattress, and at the end of a further four to six weeks can begin to walk. Little disability results from these cases in the absence of complications.

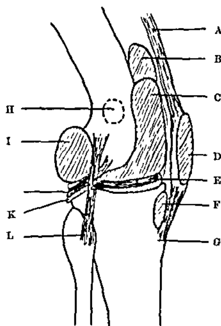


FIG 482. Diagram illustrating the correct site for the introduction of a Kirschner wire (or Stein-

[illegible]

G Tibial tuberosity. H. The ideal area for insertion of the wire. I. Semi-membranosus bursa. J. *Tendon of popliteus.* K. The bursa around the popliteus tendon. L The fibula collateral ligament of the knee.

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2. Large. The damage to the posterior rim is sufficient to make the hip joint unstable, and the fragment remains partly displaced after reduction associated with a partial subluxation of the hip. These cases demand open operation on the hip through a posterior

pelvis below the spines may give some relief, but in others it may increase the discomfort, when it should be removed. It is best applied by passing two circular turns of 4-inch elastoplast around the pelvis just below the level of the anterior spines. Free movements in bed are encouraged and the patient is allowed about as soon as he is free from pain on movement.



Fig. 487. Fracture of the anterior superior iliac spine.

2. **Fractures of a single ramus.** These are rare and due to direct violence. Usually the upper ramus of the pubis is fractured. There is local bruising and pain, but as the ring is not broken there is a freedom of movement and absence of pain on springing the pelvis which is not found in the complete fractures. The only treatment necessary is rest till the patient can get about comfortably, usually ten days to a fortnight, after which walking can be encouraged.



Fig. 488 An old un-united avulsion fracture of the ischial tuberosity in adolescence, as a result of hurdling.

3. **Fractures of the anterior superior iliac spine** may arise due to direct injury, but may also arise from the sudden spasm of the abdominal muscles and tensor fasciæ lata. There is local pain, bruising and tenderness, occasionally referred pain down the lateral cutaneous nerve of the thigh, and pain on attempts to abduct the thigh. The treatment is rest in bed with the knees flexed and abducted over a pillow. The fragment frequently unites

function can be expected, but the later onset of arthritis is to be feared.

Fractures of the Processes

1. Fracture of the ala of the ilium. This is due to direct violence or lateral crushing injuries. The displacement is as a rule spontaneously corrected by the pull of the large muscle masses attached to the fragments. The amount of bone involved may vary from a



Fig.

small wedge to almost the whole of the wing of the bone. The features of the fracture are local pain and bruising, together with pain on moving the leg on the affected side. Abnormal movement of the anterior superior iliac spine may be detected if it is attached to the fragment, or, in a few cases, it may be displaced above its normal level. Rarely the hæmatoma may press on the lateral cutaneous nerve of the thigh and cause pain. If so the hæmatoma should be incised, and drained.

Treatment is directed to making the patient more comfortable. Many patients are best nursed for a fortnight as for the fracture of the pelvic ring without displacement. A firm binder around the

on account of the frequent late development of pain in the region with little evidence as to the cause. It is possibly due to an arthritis at the sacro-coccygeal joint, or to involvement of the coccygeal nerves in the scar tissue. A neurotic element is frequently associated with the condition. The diagnosis depends on features similar to fracture of the sacrum. Radiologically the fracture may not be easy to demonstrate because of the irregularities in the normal architecture of the bone. Coccydynia can, however, arise in the absence of fracture, associated with strain of the sacro-coccygeal joint only.

TREATMENT. The displaced fracture must be reduced by a finger in the rectum, and the patient given two to three weeks rest, not necessarily all the time in bed. If any symptom of coccydynia arises hot baths and postural exercises are commenced at once. If it persists the patient is carried on by palliative methods; diathermy, or the injection of proctocaine or hydrocortisone around the bone as long as possible. Only if these methods fail is it justifiable to excise the coccyx. In some cases this will not cure the condition, the pain persisting as before.

7. **Avulsion fractures of the ischial spine** and of the lateral margin of the sacrum are seen after severe distortion of the pelvis. The sacro-tuberous and sacro-spinous ligaments run diagonally across the pelvic outlet and when it is distorted they are avulsed from their attachments. As an interesting variant, no avulsion may be seen in the early radiographs, but during recovery new bone may form in either area, indicating the original damage.

Fractures of the Sacrum

Fractures of the sacrum occur in 45 per cent. of double fractures of the pelvis, and the failure to recognise them is due to the difficulty in getting satisfactory views of the sacrum. The sacrum is a strong bone very resistant to compression, but having a weak area due to the perforations of the anterior and posterior sacral foramina between the lateral mass of the sacrum and the body of the bone. Fracture therefore most commonly involves this area running through the first, second and third sacral foraminæ to its exit just below the sacro-iliac joint. It may take the form of a fissure, a fissure with displacement, or compression. An interesting fracture is sometimes associated with these lesions, a fracture of the lower lateral margin of the bone, corresponding to the attachment of the sacrotuberous ligament. This is a ligament traction fracture due to the deformity of the pelvis at the time of injury.

RADIOGRAPHY. Clear views of the sacrum are necessary to recognise fine fissures, and the small fractures which occur around the margin of the sacro-iliac joint must often be missed in spite of good radiography. Comparison of the architecture of the bone around the

at a lower level than before, but no disability arises. The patient is allowed to sit out of bed as soon as he is free from pain, and walking is commenced at the end of three to four weeks.

4. Avulsion fracture of the anterior inferior iliac spine is due the pull of the origin of rectus femoris. The descent of the fragment is not worth correction and there is no interference with function



FIG 489. Obstetric view of pelvis to show the displacement in a fracture of the sacrum. Note the interruption in the outline of the pelvic brim. Double fracture anteriorly.

subsequently. The accident occurs to athletes. A short period of rest only is required.

5 **Fractures of the ischial tuberosity.** The most common cause is avulsion of the epiphysis to which the hamstrings are attached in young active men. Very rarely it is due to falls in the sitting position There is local pain and bruising, pain on sitting, and marked pain on stretching the hamstrings Displacement is small, and the treatment is rest in bed for three to four weeks. The patient may be nursed on the side, or an air cushion may be found to afford relief.

6 **Fractures of the coccyx** are interesting, if at times annoying,

on account of the frequent late development of pain in the region with little evidence as to the cause. It is possibly due to an arthritis at the sacro-coccygeal joint, or to involvement of the coccygeal nerves in the scar tissue. A neurotic element is frequently associated with the condition. The diagnosis depends on features similar to fracture of the sacrum. Radiologically the fracture may not be easy to demonstrate because of the irregularities in the normal architecture of the bone. Coccydynia can, however, arise in the absence of fracture, associated with strain of the sacro-coccygeal joint only.

TREATMENT. The displaced fracture must be reduced by a finger in the rectum, and the patient given two to three weeks rest, not necessarily all the time in bed. If any symptom of coccydynia arises hot baths and postural exercises are commenced at once. If it persists the patient is carried on by palliative methods; diathermy, or the injection of proctocaine or hydrocortisone around the bone as long as possible. Only if these methods fail is it justifiable to excise the coccyx. In some cases this will not cure the condition, the pain persisting as before.

7. **Avulsion fractures of the ischial spine** and of the lateral margin of the sacrum are seen after severe distortion of the pelvis. The sacro-tuberous and sacro-spinous ligaments run diagonally across the pelvic outlet and when it is distorted they are avulsed from their attachments. As an interesting variant, no avulsion may be seen in the early radiographs, but during recovery new bone may form in either area, indicating the original damage.

Fractures of the Sacrum

Fractures of the sacrum occur in 45 per cent. of double fractures of the pelvis, and the failure to recognise them is due to the difficulty in getting satisfactory views of the sacrum. The sacrum is a strong bone very resistant to compression, but having a weak area due to the perforations of the anterior and posterior sacral foramina between the lateral mass of the sacrum and the body of the bone. Fracture therefore most commonly involves this area running through the first, second and third sacral foraminæ to its exit just below the sacro-iliac joint. It may take the form of a fissure, a fissure with displacement, or compression. An interesting fracture is sometimes associated with these lesions, a fracture of the lower lateral margin of the bone, corresponding to the attachment of the sacrotuberous ligament. This is a ligament traction fracture due to the deformity of the pelvis at the time of injury.

RADIOGRAPHY. Clear views of the sacrum are necessary to recognise fine fissures, and the small fractures which occur around the margin of the sacro-iliac joint must often be missed in spite of good radiography. Comparison of the architecture of the bone around the

at a lower level than before, but no disability arises. The patient is allowed to sit out of bed as soon as he is free from pain, and walking is commenced at the end of three to four weeks.

4. Avulsion fracture of the anterior inferior iliac spine is due the pull of the origin of rectus femoris. The descent of the fragment is not worth correction and there is no interference with function



Fig. 489. Obstetric view of pelvis to show the displacement in a fracture of the sacrum Note the interruption in the outline of the pelvic brim. Double fracture anteriorly

subsequently The accident occurs to athletes. A short period of rest only is required.

5. **Fractures of the ischial tuberosity.** The most common cause is avulsion of the epiphysis to which the hamstrings are attached in young active men Very rarely it is due to falls in the sitting position. There is local pain and bruising, pain on sitting, and marked pain on stretching the hamstrings. Displacement is small, and the treatment is rest in bed for three to four weeks. The patient may be nursed on the side, or an air cushion may be found to afford relief.

6. **Fractures of the coccyx** are interesting, if at times annoying,

In any pelvic fracture of any severity there is likely to be some lower abdominal rigidity whether there is injury to a viscus or not. It is possibly due to retroperitoneal hæmorrhage causing peritoneal irritation. It can be sufficiently marked to confuse the issue when there is suspicion of a ruptured viscus. In the case of the bladder more exact information can be obtained, but in the case of suspected injury to bowel careful observation or laparotomy may be needed (see p. 292).

Injury to the urethra. The triad of symptoms indicating this are perineal bruising, the escape of blood from the urethra, and

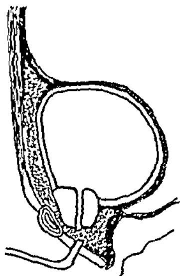
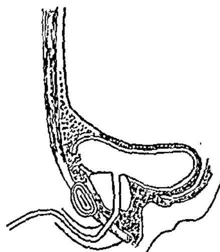


Fig. 490. Intrapelvic rupture of the prostatic urethra, showing the course of the extravasation.



Fi

retention of urine, to which a fourth may be added, extravasation of urine, *a complication to be avoided at all costs. In a suspected* case, unable to hold urine any longer, or in whom the bladder is distended and giving pain, it is justifiable to puncture the bladder suprapubically as often as is necessary till he can be given the correct *treatment to avoid extravasation.*

Extrapelvic rupture of the urethra. 1. May be in the bulb below the compressor urethra. Spasm of this muscle then gives rise to retention.

2. May be in the bulb above the compressor urethra, when early extravasation will occur.

In the presence of any of the signs mentioned, steps must be taken to clear up the diagnosis and institute treatment as soon as possible. This can only be satisfactorily done in the operating theatre. After cleaning up the *anterior urethra, a size 8 gum elastic*

sacral foramina on both sides is necessary. The pattern should be unbroken on both sides if the bone is normal. Narrowing of the bone on one side may be obvious (Fig. 486). A most important view in doubtful cases, and in cases in which full details of the displacement are wanted, is the obstetric view of the pelvis. Irregularity in level of the brim of the pelvis is common in fractures in this region (Fig. 489).

NEUROLOGICAL FEATURES. The treatment of the bone injury is practically impossible, but neurological features are often associated with such cases and these demand treatment. The lesion commonly present is due to pressure on the first and second roots of the sacral plexus. This produces an incomplete lesion and this, combined with the vagueness of root syndromes generally, may make the syndrome difficult to recognise. It is obviously similar to that of a prolapsed disc but involves the second sacral root which is not usually pressed on by a disc. The characteristic features of pressure on S.1 and S.2 roots are :—

1. Paræsthesiæ, and varying degrees of loss of sensation of light touch and pin prick over the outer side of the leg (S.1, S.2 area).
2. Loss of muscle power and wasting in the calf, the hamstrings and the buttocks, in that order of severity. Biceps femoris is sometimes almost completely wasted.
3. Loss of diminution of the ankle jerk.

There is, of course, no interference with bowel or bladder function. The treatment is confined to trying to maintain the tone and development of the affected muscles, by exercise, electrical stimulation and massage. It is characteristic of the lesion that, owing to the retention of some voluntary power in all muscles, the condition is not recognised till disproportionate wasting in the muscles described, on the injured side calls for explanation. The prognosis is good in the average case, satisfactory recovery taking place. As in neurological lesions elsewhere, the more complete the lesion at first the worse the ultimate recovery.

Transverse fracture of the sacrum just below the sacro-iliac joints, *i.e.*, of that part which lies in the true pelvis, may occur from falls or kicks. The displacement is usually small and the condition should be treated by early exercises, particularly exercises involving the pelvic diaphragm

COMPLICATIONS OF FRACTURE OF THE PELVIS

Death in fractures of the pelvis is commonly due to the associated severe injuries In 10 per cent. of fractures of the pelvis alone there are associated visceral injuries which may cause serious trouble. The urethra is commonly injured and if the bladder is full it may be ruptured. Injuries to the vagina, rectum, or small intestine are much less common. Still more rarely the pelvic blood vessels are torn, or the sciatic nerve injured If the nerve is paralysed this is usually temporary and demands no other treatment than the prevention of foot drop and electrical stimulation of the muscles.

depending on the quantity of urine secreted, the extent of the rupture, and the degree to which it is occluded by adjacent soft tissues and clot. The same factors will likewise affect the ability to micturate. Rupture of the intra-pelvic urethra generally occurs at the apex of the prostate and is often complete. Tearing of the pubo-prostatic ligaments, or displacement of the pubic rami allows the prostate to fall backwards rendering spontaneous direct healing impossible. Urinary extravasation is limited for a time by contraction of the internal urinary sphincter but effusion of blood occurs in the peri-vesical tissues.

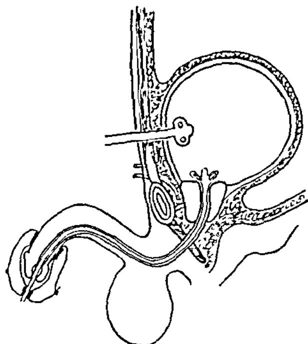


FIG. 493. The treatment of intrapelvic rupture of the urethra. A catheter is inserted supra-pubically, and below this the cave of Retzius is drained. Another catheter is passed through the urethra and tied in.

The degree of shock which frequently accompanies severe pelvic injuries may render the diagnosis difficult. Any suspicion of damage aroused by the radiographic findings may, however, be supported by clinical evidence of increasing suprapubic discomfort and by interference with the act of micturition. The escape of blood from the external urinary meatus or the passage of bloodstained urine, particularly if associated with a suprapubic swelling or displacement of the prostate on rectal examination, prompt the need for urgent investigation and treatment. In this event, when the initial shock has been combated, an attempt should be made to pass a small Tiemann's catheter. In the case of rupture of the intra-pelvic urethra this will probably prove unsuccessful, and arrangements must be made for the performance of suprapubic cystostomy drainage at the earliest opportunity. This will secure diversion of the urine

catheter of the coude type is passed. If it passes easily and clear urine is withdrawn then serious injury to the urinary tract is excluded. If difficulty is met with accompanied by pain and hæmorrhage, but the catheter can be passed, then partial rupture of the urethra has occurred. One must then decide between leaving the catheter tied in, with risk of sepsis, and later stricture, or treating the case as a complete rupture, with perineal drainage in the hope of avoiding later scarring. Failure to pass the catheter indicates complete rupture. An attempt is then made to find the divided ends of the urethra in the perineum by passing a sound as far as possible along

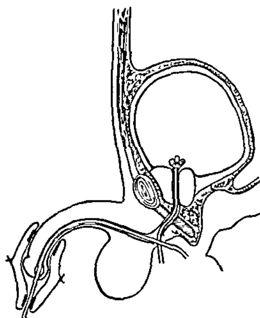


FIG. 492 The treatment of extrapelvic rupture of the urethra. Catheters are inserted through both portions of the urethra, and brought out the perineal wound.

the penile urethra and cutting down on the end of this The difficulty of finding the proximal end is notorious, and if perineal search fails a suprapubic incision must be made and retrograde catheterisation carried out. The two catheters are brought out through the perineum and the tissues sutured around them with drainage If extravasation has occurred adequate incisions and drainage is provided in the affected tissues.

Rupture of the bladder and intrapelvic urethra. The combined incidence is variously estimated at between 10 and 20 per cent., either condition (particularly injury to the urethra) being more likely when the fracture involves the pubic rami Rupture of the bladder is generally extra-peritoneal though, if the viscus is distended at the time of the injury, an intra-peritoneal tear may result. Extravasation of bloody urine will occur to greater or lesser amount

CHAPTER XXVII

FRACTURES OF THE FEMUR

Surgical anatomy. Development. The primary centre for the shaft appears at the seventh week. Secondary centres appear as follows :—

Head . . .	First year.	Fuse with the shaft about eighteen years.
Greater tuberosity .	Third year.	
Lesser tuberosity .	Thirteenth year.	
Lower epiphysis .	Shortly before birth.	Unites twenty-three to twenty-four years.

The femoral neck in the adult makes an obtuse angle with the shaft, which vasies from individual to individual, and is less in the female, but averages about 120°. The neck is also inclined forward at an angle of 10° to 15° from the frontal plane. It is to be regarded as a continuation of the shaft of the bone, which is modified by growth, so that it lies at the angle described. To it is attached the greater tuberosity and the lesser tuberosity. In accordance with the laws of ossifying bones a greater density of bone is laid down on the inside of the curve of the neck, forming the calcar femorale. The outer side of the curve which becomes the upper part of the neck is modified to cancellous bone and *incorporated in the trochanter, the internal trabecular formation* corresponding to the lines of stress through the bone. The strength of the calcar femorale is the determining factor in the position of fractures of the upper end of the femur, and a spike of it impacted into the cancellous bone of the head may be the cause of failure to reduce a subcapital fracture.

The blood supply of the head of the bone is derived from arteries in the shaft of the bone, vessels running along the sapsule of the joint and passing back along the retinaculæ, and the artery of the ligamentum teres. This extensive anastomosis consequently requires considerable displacement of bone before the blood supply of the head is interfered with.

The epiphyseal line for the head is entirely intracapsular, that for the great trochanter partly so. At the lower end the epiphysis is intracapsular anteriorly. It is also to be noted that the adductor tubercle is on the metaphysis and not on the epiphysis.

Fractures of the Upper End of the Femur

Fractures of the head of the femur . . .		0·5	per cent.
Fractures of the neck of the femur . . .		33	,,
Medial or subcapital	*Abduction*	12	,,
	Adduction	88	
Lateral	*Adduction*		,,
Pertrochanteric fractures		62	,,
Separation of the epiphysis for the head of the femur		3	,,
Fracture of the greater trochanter . . .		1	,,
Fracture of the lesser trochanter . . .		0·5	,,

and, if the patient's condition precludes any further procedure, will allow a period for recovery before reparative surgery is instituted. On the other hand, if conditions are more favourable, an attempt should be made at the time to obtain apposition of the ruptured ends of the urethra by instrumental manipulation and to retain this relationship with an indwelling Foley's catheter (Fig. 493). Withdrawal of the catheter after ten days should result in the re-establishment of the urinary flow, following which suprapubic diversion can be discontinued. Subsequent stricture is common, and periodic instrumentation may be required.

In the case of suspected rupture of the bladder the urethral catheter will generally pass with little difficulty, but the result may be equivocal. If a small rupture is present, or the rent is occluded by soft tissue, a quantity of urine may be obtained from the bladder. Similarly, should the catheter pass through the rent a quantity of extravasated urine may escape from the extra-vesical space. The introduction of measured quantities of fluid for estimation on withdrawal, or investigation by cystoscopy and cystography may all prove fallacious and are not to be recommended at a time when the patient's condition is likely to be precarious. The withdrawal of blood-tinged urine on catheterisation supported by the radiographic findings and clinical evidence of extravasation form a sufficient indication for urgent suprapubic exploration. The immediate aim again is to secure suprapubic drainage and at the same time to repair the rupture if practicable. Particular care is required in the post-operative treatment of these cases since the incidence of urinary infection and stone formation is considerable, the risk being aggravated by the need for recumbency imposed during treatment of the accompanying fracture. Similar methods should be adopted to those outlined in the treatment of the paraplegic bladder (p. 280).

FURTHER READING

PEABODY. "Disruption of the Pelvis with Luxation of the Innominate Bone," *Arch Surg*, 1930, 21, 970.

COHEN. "Avulsion Fracture of the Ischial Tuberosity," *J. Bone and Joint Surg*, 1937, 19, 1138.

CONWAY. "Fractures of the Pelvis," *Am. J. Surg.*, 1935, 30, 69. (Recommends the rather doubtful procedure of abdominal puncture for intra-abdominal injury. Laparotomy is safer. Further references.)

WATSON JONES. "Dislocation and Fracture-Dislocation of the Pelvis," *Brit. J. Surg.*, 1938, 25, 773–781.

WAKELEY. "Fracture of the Pelvis," *Brit. J. Surg.*, 1929, 17, 22. (Gives the figure of 11 per cent. for visceral complications.)

BONNIN, J. G. "Sacral Fractures and Injuries to the Cauda Equina," *J. Bone and Joint Surg.*, 1945, 27, 113.

TAYLOR, R. G. "Pelvic Dislocations," *Brit. J. Surg.*, 1942, 30, 126–132.

HOLDSWORTH, F. W. "Dislocation and Fracture Dislocation of the Pelvis," *J. Bone and Joint Surg.*, 1948, 30B, 461.

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the femoral neck, [illegible]
act through the fracture line, and will tend to impact. Fractures just below the head (medial, subcapital, or intracapsular) are more frequently oblique and show a greater tendency to unite than the vertical fracture which is more characteristic of the lateral (extracapsular) fracture of the neck. Distinguishing between these two fractures by the terms intra and extra capsular has been shown to be meaningless as the so-called intracapsular fracture is extracapsular posteriorly. The terms belong to the days when the synovial fluid was supposed to exert a deleterious effect on union.

The degree of obliquity of the line of fracture is far more important than its site.

Any tendency of the upper fragment to be abducted would increase the impacting force of the body weight, and so promote union. This is seen in the classical abduction fracture which is always combined with impaction. The fracture united readily, and with a good result. Treatment to obtain union of the fractured neck of the femur is therefore directed towards two objects :

1. Fixation of the fragments and avoidance of a shearing strain.
2. Impaction of the fracture, or the alteration in the line of transmission of the body weight so that it acts largely as a compression force on the fracture site.

The influence of this last-mentioned factor is seen in the union of old ununited fractures of the neck of the femur after a Lorenz or McMurray osteotomy. Only one line of treatment conforms to these principles and that is operative fixation with impaction of the fracture, which is most efficiently carried out with the Smith-Petersen nail.

The examination of the hip. A summary of the most important clinical observations to be made is given, but these are often of academic interest only, and radiographs are of the greatest importance.

1. Measuring the length of the limb. This is measured from the anterior superior iliac spine to the internal malleolus, with both legs extended, the tape running on the inner aspect of the patella, and with the pelvis level, to avoid error from adduction or abduction of the legs.

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Fractures of the head. Fissure fractures are rare and almost impossible to diagnose except at open operation. They may be suspected after severe injury to the hip, such as dislocation, in which the joint movements do not return as quickly as expected. Most fractures of the head take the form of chip fractures in association with dislocation of the hip, and it may sometimes be difficult to say whether the fragment in the joint comes from the posterior lip of the acetabulum or the head. *Undisplaced* fragments are left, and the hip is freed from pressure by high traction (10 to 15 lbs.) for a few weeks, and then active non-weight bearing exercises commenced. Displaced fragments should be removed by open operation, if preventing reduction. If not they should be left as the results are much better than might be expected.

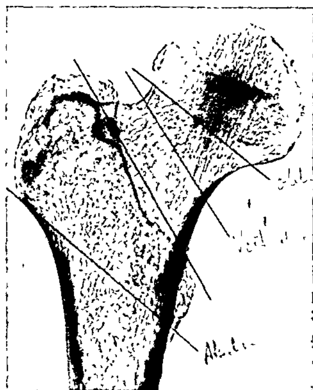


FIG 494. Fracture sites in the upper end of the femur. Subcapital fractures occur most frequently between the two upper lines. Pertrochanteric fractures occur between the two *lower lines. In between these areas is a strip* of bone in which the so-called lateral fracture of the neck of the femur occurs. More important than the site of fracture is the obliquity of the fracture, *i e.*, its relation to the axis of the neck of the femur.

Fractures of the Neck of the Femur

The fact that the lesion is most common in *elderly people*, associated with senile decalcification of bones, has lent to the treatment of the fracture peculiar difficulties which are still only partly resolved. The lesion is *slightly more common in* women, showing, like Colles's fracture, a tendency to be associated with obesity, indicating that the decalcification may be partly an endocrine disturbance. To this factor are added two others, the neck of the bone is inclined more nearly at a right angle in women and this increases the leverage possible, and the bones are thinner.

The situation of the fracture, lying across a curve in a bone which shares with another the weight of the body and is subject to the full leverage of the limb, increases the stress and strain to which the repair line of the fracture is subjected. As in fractures elsewhere impaction strain aids union, but shearing strain delays it. In fractures of the neck of the femur the nearer the fracture line is to

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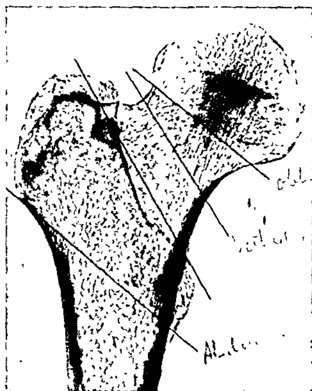


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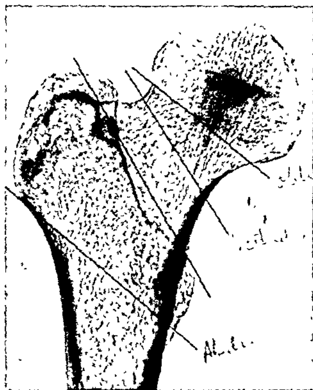


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the vertical the less the impacting strain and the greater the shearing strain. A minor factor acting in the same manner is the angle of the femoral neck, the more oblique the neck the more the weight will act through the fracture line, and *will tend to impact.* Fractures just below the head (medial, subcapital, or intracapsular) are more frequently oblique and show a greater tendency to unite than the vertical fracture which is more characteristic of the lateral (extra-capsular) fracture of the neck. Distinguishing between these two fractures by the terms intra and extra capsular has been shown to be meaningless as the so-called intracapsular fracture is extracapsular posteriorly. The terms belong to the days when the synovial fluid was supposed to exert a deleterious effect on union.

The degree of obliquity of the line of fracture is far more important than its site.

Any tendency of the upper fragment to be abducted would increase the impacting force of the body weight, and so promote union. This is seen in the classical abduction fracture which is always combined with impaction. The fracture united readily, and with a good result. Treatment to obtain union of the fractured neck of the femur is therefore directed towards two objects :

1. Fixation of the fragments and avoidance of a shearing strain.
2. Impaction of the fracture, or the alteration in the line of transmission of the body weight so that it acts largely as a compression force on the fracture site.

The influence of this last-mentioned factor is seen in the union of old ununited fractures of the neck of the femur after a Lorenz or McMurray osteotomy. Only one line of treatment conforms to these principles and that is operative fixation with impaction of the fracture, *which is most efficiently carried out with the Smith-Petersen nail.*

The examination of the hip. A summary of the most important clinical observations to be made is given, but these are often of academic interest only, and radiographs are of the greatest importance.

1. Measuring the length of the limb. This is measured from the anterior superior iliac spine to the internal malleolus, with both legs extended, the tape running on the inner aspect of the patella, and with the pelvis level, to avoid error from adduction or abduction of the legs.

2. Estimating the position of the trochanter.

(*a*) Nelaton's line. A line from the anterior superior iliac spine to the ischial tuberosity *crosses the tip of the great trochanter.*

(*b*) Bryant's triangle. This consists of dropping a vertical line from the anterior superior iliac spine in the recumbent patient and measuring *the distance the tip of the trochanter lies below it.*

(*c*) Shoemakers' line. A line prolonged from the great trochanter through the anterior iliac spine, normally crosses the mid-line at the umbilicus or above it. If the trochanter is elevated it lies below the umbilicus.

Fractures of the head. Fissure fractures are rare and almost impossible to diagnose except at open operation. They may be suspected after severe injury to the hip, such as dislocation, in which the joint movements do not return as quickly as expected. Most fractures of the head take the form of chip fractures in association with dislocation of the hip, and it may sometimes be difficult to say whether the fragment in the joint comes from the posterior lip of the acetabulum or the head. Undisplaced fragments are left, and the hip is freed from pressure by high traction (*10 to 15 lbs.*) for a few weeks, and then active non-weight bearing exercises commenced. Displaced fragments should be removed by open operation, if preventing reduction. If not they should be left as the results are much better than might be expected.



Fig. 494. Fracture sites in the upper end of the femur. Subcapital fractures occur most frequently between the two upper lines. Pertrochanteric fractures occur between the two lower lines. In between these areas is a strip of bone in which the so-called *lateral fracture* of the neck of the femur occurs. More important than the site of fracture is the obliquity of the fracture, *i.e.*, its relation to the axis of the neck of the femur.

Fractures of the Neck of the Femur

The fact that the lesion is most common in elderly people, associated with senile decalcification of bones, has lent to the treatment of the fracture peculiar difficulties which are still only partly resolved. The lesion is slightly more common in women, showing, like Colles's fracture, a tendency to be associated with obesity, indicating that the decalcification may be partly an endocrine disturbance. To this factor are added two others, the neck of the bone is inclined more nearly at a right angle in women and this increases the leverage possible, and the bones are thinner.

The situation of the fracture, lying across a curve in a bone which shares with another the weight of the body and is subject to the full leverage of the limb, increases the stress and strain to which the repair line of the fracture is subjected. As in fractures elsewhere impaction strain aids union, but shearing strain delays it. In fractures of the neck of the femur the nearer the fracture line is to

mid-line may be applied. The restoration of the limb to its normal length and its maintenance *is an important guide to the reduction* and retention of the fracture.

PAIN. This is variable. It is minimal in the impacted abduction fractures where movements of the hip may be passively elicited. The pain may be referred to the knee. Tenderness is always present and the situation of maximum pain, over the head of the femur or over the trochanter, may help to localise the fracture.

SWELLING. In fractures of the neck it is maximal over Scarpa's triangle, and in the pertrochanteric fractures in the lateral aspect of the thigh around the trochanter. Bruising appears in 1 to 3 days at these sites.

Other signs are the relaxation of the ilio-tibial band due to shortening, which allows the fingers to be pressed in more deeply over the tip of the trochanter if the sign is not obscured by swelling. Rotation of the thigh at the fracture site instead of through the hip is painful to elicit and difficult to observe. Telescopic movement is also painful and obscured by muscle spasm or impaction.

IMPACTED FRACTURES. An impacted fracture may occur in both the neck and in the pertrochanteric region. The signs, such as pain, shortening and swelling all tend to be less obvious. Movements at the hip may be passively elicited and crepitus is absent. The impaction can usually be seen radiologically. Abduction fractures are always impacted, due to a combination of the action of the force producing them and the direction of the fracture line which is almost at right angles to the line of transmission of the body weight, and this tends to further impaction on weight bearing.

To distinguish clinically between pertrochanteric fractures and fractures of the neck of the femur is not usually easy, though the following points may help. Owing to the bone on the posterior aspect of the trochanter being softer there is a greater eversion of the limb in pertrochanteric fractures. The shortening is greater and the swelling and pain is localised to the trochanteric region.

X-RAYS. *As with fractures elsewhere* correct orientation can only be obtained with films taken in the antero-posterior direction and in the lateral direction. An apparently good position in the A.P. film may show gross displacement on the lateral plate. Similarly care must be taken over the rotation of the limb, not only in reduction, but in the diagnosis of the actual fracture. With the limb everted the plate shows a prominent lesser trochanter, and the intertrochanteric line which is posterior crosses the neck of the femur, while in the inverted limb the lesser trochanter passes behind the femur, the calcar femorale becomes more definite, and the intertrochanteric line lies lateral to the neck (Figs. 495, 496).

(*d*) Normally lines joining the two anterior superior iliac spines, and the tips of the two trochanters are parallel. If the trochanter is elevated they are angulated.

3. The trochanter may be nearer the mid-line than normal. This is best measured with callipers, but it may be roughly taken by measuring from the mid-line to the anterior border of the trochanter.

4. Testing hip movements.

(*a*) Flexion. Flex the sound leg fully to overcome compensatory lordosis, and for comparison. A fixed flexion deformity may become obvious.

(*b*) Extension. Lift the limb off the couch with the patient lying on his face, or carry the limb backwards on the arm with the patient lying on the side. Normally 15°.

(*c*) Rotation. Roll the calf on the couch with the flat of the hand, and compare with the other side, using the foot as a convenient indicator of degree.

(*d*) Abduction. Abduct the leg, steadying the pelvis, and compare.

(*e*) Adduction. Cross the thigh over the thigh of the opposite side. Normally it should cross the middle third.

Physical signs in fracture of the upper end of the femur. In order to avoid repetition the general features which are common to all fractures will be outlined and the differences of individual fractures mentioned under their own heads.

History. Characteristically one of slight violence in old people. The average age for fractures of the neck is about ten years less than for pertrochanteric fractures, where the highest incidence is between sixty and seventy years. The strain is usually a rotational one caused by stumbling with the foot fixed, *e.g.*, against a step. Less frequently there is a fall on the extended leg. Abduction fractures are frequently associated with falls on to the outer aspect of the great trochanter, characteristically seen when a 'bus starts suddenly and throws the patient to the floor on the side. Any elderly person who sustains a fall from which he is unable to rise, and after which the use of one leg is lost, has in all probability a fracture of the upper end of the femur, and this must be proved or disproved by radiography.

Inspection. This will show a patient suffering a variable amount of shock, often not very great, lying with the limb flat on the bed and the leg externally rotated.

Disability. This is least in abduction fractures, with which the patient may have made some attempt to walk. In most cases it is complete and the patient cannot make any movement of the limb at the hip.

Shortening. This may be measured by the elevation of the trochanter or the alteration in the length of the limb. It varies from an undetectable amount to 2 inches. At the same time the tests for the elevation of the trochanter and its approximation to the

"Abduction" fractures can be divided into two groups on radiological evidence :

1. The firmly impacted fracture,
2. The insecurely impacted fracture,

though the distinction between the two is by no means easy to make in all cases, and disappointment will be experienced in some apparently firmly impacted fractures becoming disimpacted and passing into the adduction fracture. If one is firmly convinced of the strength of the impaction and the deformity is small it is permissible to treat the fracture with a short hip spica (Fig. 110). After a period of bed exercises for three weeks, walking may be commenced, at first on crutches, and then with a stick. The fracture should not become disimpacted and union should be rapid, the spica being removed between the sixth and the eighth week.

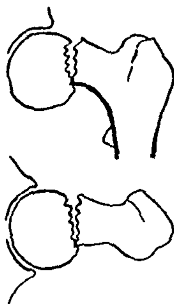


Fig. 497. Antero-posterior and lateral views of an "adduction" fracture of the femoral neck.

In practice owing to the risk of disimpaction and to the limitation of exercise it proves more satisfactory to pin all fractures. With slight displacement the head may be pinned in the impacted position if the displacement is more marked it is reduced and the case proceeded with as if it were an adduction fracture.



Fig. 498. Antero-posterior and lateral views of an "abduction" fracture of the femoral neck.

Adduction Fractures of the Neck of the Femur

Medial. (Subcapital, intracapsular.)	Discussed together.
Lateral. (So-called extracapsular.)	

The medial fracture is the more common, but there is often difficulty in deciding to which group a case belongs, owing to the obliquity of the fracture line. Generally speaking, medial fractures tend to be more oblique, while lateral fractures tend to be vertical. More trouble with the blood supply to the head can be expected in medial fractures. The vertical fracture is, however, more difficult to impact, and more

up about the eighth week, and if of suitable physique taught the use of crutches. Union will be firm about the twelfth week and weight bearing may be commenced. Any signs of displacement or non-union during treatment should encourage fixation with a pin or a pin and graft

In young patients (under eighteen years), in whom non-union is not to be feared, the method is still a good one, and to be recommended. At present in old people the method is applied to patients unfit for operative treatment, and so its results are poor.



Fig. 501a. The reduction of a fracture of the femoral neck by manipulation. First stage. Traction.



Fig. 501b. Second stage. Traction combined with internal rotation.

Whitman's plaster. This method is not a satisfactory one as the proportion of unions obtained in the best hands is only 60 per cent., and the method is liable to lead to stiffness of the knee and hip on the affected side. Added to this it is not an easy method to apply to an old patient, and while the patient can be moved more easily the patient himself finds more difficulty in moving. A few active thin patients can walk in a Whitman plaster with a walking iron applied to the plaster and the heel on the sound side built up If this can be done many of the objections to the method are done away with, but it is rarely so (Fig. 109).

Method. The fracture, if reduced by continuous traction, will require little manipulation when the patient is on the orthopædic table, which saves the patient some shock. If unreduced the hip is reduced by manipulation, the leg being forcibly extended, inwardly rotated, and abducted, while the other leg is pulled on to fix the pelvis. The feet are then attached to the foot pieces, and the legs held in slight abduction and internal rotation. An X-ray is taken to be certain reduction has been carried out. If this is satisfactory the leg

the patient requires some exercises to restore movements to the injured limb, and as soon as possible is fitted with a walking calliper which is worn for a further three to six months. X-ray control is exercised throughout the proceeding. Swelling of the leg after removal of the plaster is controlled by an elastic knee cap and an Unna's paste stocking below.

If the patient is able to get about in his plaster the proceeding is the same, but if non-union is present at the end of three months it is reasonable to re-apply the plaster for a further three months.

This method is suitable for the rare case of fracture of the neck of the femur in young children when the plaster is required for ten weeks only, the child being kept in bed.

Operative fixation of fractures of the neck of the femur. For the reasons given previously this is the best method of treating all fractures of the femoral neck. There has been some discussion about the best time of operation. There is much to be said for immediate operation if the patient's condition is good and facilities available. The fracture is most frequently encountered in elderly patients, and there has often been delay in getting them into hospital, consequently they arrive tired and in poor condition and it is advantageous to give them twenty-four hours rest under continuous traction. This reduces the fracture, avoids undesirable pressure on any surviving blood vessels, and the need to commence operation by manipulative reduction. After reduction of the fracture by traction and the investigation of the patient's general condition, the decision to operate is made, and as the cases refused operation nearly all die from complications, it is permissible to take some risks. The choice of operation lies between the following methods, each suitable to particular cases.

1. Open operation, exposing the hip joint and fracture, accompanied by a Smith-Petersen pin. The exposure of the hip increases the shock of the operation greatly, and has been superseded by X-ray controlled methods. It may be necessary in the few cases of fracture which cannot be reduced by continuous traction or manipulation.

2. Insertion of a bone graft. This usually is an autogenous peg cut from the fibula. While encouraging union, it does not prevent the shearing strains at the fracture site, and the results are not so satisfactory as from nailing, though it may be the method of choice in young patients. Pencil grafts may be inserted around a nail to hasten union, where it is considered it may be delayed (Fig. 518).

3. Smith-Petersen nail. This nail of stainless steel has three flanges which obtain a good grip on the head and so prevent rotation.

It serves as a guide over which accurate and forcible impaction can be carried out and produces a high percentage of bony unions (90 per cent.). Carried out by a "blind" method using X-ray control the method is not productive of shock, and by allowing the patient "the freedom of the bed" materially increases his comfort and reduces the number of complications.

4. SMITH-PETERSON NAIL ACCOMPANIED BY A BONE GRAFT. This is an endeavour to combine the advantages of methods 2 and 3. It ma[illegible] or [illegible] whi[illegible] nec[illegible] fractures where the verticality of the fracture line suggests difficulty in obtaining union by a nail alone.



FIG. 502. Smith-Petersen nail, showing the central canal for the guide.

To describe in detail the various operative methods is beyond the scope of this book, but a brief outline of the established methods is given below. The development of the X-ray controlled technique has brought many instruments to light designed to facilitate the



FIG. 503. Th[illegible] are intro[illegible] or by th[illegible] screen. [illegible]

insertion of the nail. The superiority of one method over another is debatable, the most important part of any technique being the surgeon's familiarity with it, and its limitations. As a general guide the simplest of methods will be outlined.

1. Reduction. This is done by continuous traction beforehand if possible, but if this is not satisfactory the patient is manipulated on the table. Leadbetter's manœuvre (Figs. 501A, 501B), consisting of

Fig. 504. Watson-Jones guide.

strong traction combined with forced internal rotation is not often used. Reduction is tested by noting whether the foot externally rotates when placed on a flat surface.

2. The highest point of the femoral head is now marked by taking a point ½ inch below the mid-point of a line joining the symphysis pubis and the anterior superior iliac spine. A skin clip is placed here, with, if preferred, a further clip an inch on either side of it, on a line parallel to Poupart's ligament. If desired clips may be placed over the greater tuberosity.

3. Antero-posterior and lateral X-rays are now taken. These show the reduction of the fracture and the relation of the head to the clips. The correct angle for the insertion of the nail in the frontal plane can now be appreciated. The slight forward angulation of the neck may be allowed for by directing the wire up to the anterior superior iliac spine of the opposite side.

It is however much easier to invert the limb till the neck of the femur is parallel with the top of the table, and insert the wire in this plane.

4. An incision is now made over the great trochanter, under local or general anæsthesia. The bone is exposed below the line of attachment of the vastus lateralis to the



Fig. 505. The lateral view of the neck being satisfactory, the pin is driven home over the wire.

trochanter. The point of entry for the guide is well below this. A small area of cancellous bone is removed here with a wide (¼ inch) drill or a small gouge.' A thick Kirschner wire or a Watson-Jones graduated guide is now pushed into the bone from this point in the calculated direction. If desired a second wire at a slightly different angle may be inserted. The procedure may be facilitated by doing it under the X-ray screen, though screening is generally unwise.

5. Further X-rays are now taken in the antero-posterior and lateral direction. On these the correctness of the position of the

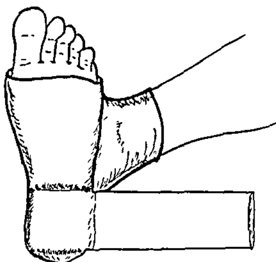


Fig. 506. Cross-piece of wood attached to the heel of a plaster shoe to prevent eversion of the foot. The same effect may be achieved by nailing it on to the heel of an ordinary shoe.

guide is judged, and the most suitable guide selected. The other is removed. The ideal position of the guide is central in the lateral view, and running tangential to the calcar femorale but parallel with the centre line of the neck, in the antero-posterior film. The length of nail necessary can be calculated directly from the Watson-Jones guide or, if Kirschner wires of a fixed length are used, from the amount of wire extending beyond the trochanter. A nail ½ inch short of the distance between joint line and trochanter is selected. This is to allow for impaction of the fracture over the nail.

6. The nail is now placed on the guide wire and driven home over it. The guide wire is withdrawn and the position checked in antero-posterior and lateral X-rays. If satisfactory the fracture is now impacted by several blows on the trochanter with the impacting instrument after traction is relaxed. This should cause the nail head to protrude a little from the surface, and it is then driven home. The wound is then closed.

7. The use of a cross screw or pin has been recommended to avoid the risk of the nail slipping out. This risk is only present in elderly

patients with atrophic bones, which grip the pin very lightly. It is a wise precaution in such patients. A separate screw is to be recommended as any slight angulation of the pin may snap a small cross pin.

The Ideal Position of the Nail

The object of the operation is to impact the fracture accurately over the nail to encourage union. The nail then serves as an internal splint to stop shearing strains at the fracture site. The second and almost equally important point is to facilitate use of the limb as soon as possible. *Sitting the patient up in bed, and even sitting the patient out on the day following operation may be of great general value in the old, and can be safely carried out with an indifferent pin.* Bed exercises may also be given. *There is no exercise so beneficial as active weight bearing on the injured limb and the pin should be inserted so that this is possible almost immediately after the operation.*

The conditions which must be fulfilled for safe early weight bearing are :—

1. A good grip on the femoral head.
   (*a*) A pin sufficiently long (better too long than too short).
   (*b*) A pin well placed in the head.
2. A well-impacted fracture line.
3. A pin obtaining a strong grip on the trochanter.
   (*a*) A long pin, the nearer to vertical the pin the better its support.
   (*b*) A pin lying in contact with the calcar femorale, *i.e.*, lying tangential to its curve, so that, should the fracture disimpact, the pin cannot be forced lower in the femoral neck.

The insertion of a pin in the ideal position is only achieved by meticulous attention to detail, and as the result of experience. The principal point which determines the correct set of the pin is to start with a small gouge hole for the entry of the guide wire sufficiently far down the femoral shaft, about the level of the lower margin of the lesser trochanter. Pins commenced above this level tend to lie too transversely, and so may be displaced downward in the femoral neck on weight bearing carrying the femoral head down with them.

Almost immediate weight bearing is the ideal, and is possible with an ideally placed pin. The date at which weight bearing is commenced is decided on the quality of the pin, it should seldom have to be delayed for more than two to three weeks (Fig. 509). While waiting, a regime of active bed exercises and hip exercises is given and the patient allowed to sit out. To keep a patient in bed

trochanter. The point of entry for the guide is well below this. A small area of cancellous bone is removed here with a wide ($\frac{1}{4}$ inch) drill or a small gouge.' A thick Kirschner wire or a Watson-Jones graduated guide is now pushed into the bone from this point in the calculated direction. If desired a second wire at a slightly different angle may be inserted. The procedure may be facilitated by doing it under the X-ray screen, though screening is generally unwise.

5. Further X-rays are now taken in the antero-posterior and lateral direction. On these the correctness of the position of the

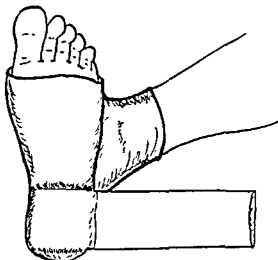


FIG. 506. Cross-piece of wood attached to the heel of a plaster shoe to prevent eversion of the foot. The same effect may be achieved by nailing it on to the heel of an ordinary shoe.

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6. The nail is now placed on the guide wire and driven home over it. The guide wire is withdrawn and the position checked in antero-posterior and lateral X-rays. If satisfactory the fracture is now impacted by several blows on the trochanter with the impacting instrument after traction is relaxed. This should cause the nail head to protrude a little from the surface, and it is then driven home. The wound is then closed.

7. The use of a cross screw or pin has been recommended to avoid the risk of the nail slipping out. This risk is only present in elderly

three months after nailing a subcapital fracture is an error of judgment or a confession of failure.

Techniques of Nail Insertion

The simple method described is a composite method, points being taken from various techniques. The aim of all special techniques is to devise a method for inserting the wire accurately in the femoral neck, allowing for the angulation of the neck of the femur in the frontal plane, and the forward inclination of the head of 17 degrees from this plane. It is this latter inclination which is the most difficult to make allowances for.

The Bailey Guide

In this method a metal tongue is run along the anterior surface of the femoral neck by open operation. A wire inserted parallel to this will thus have the required forward inclination. The angle in the frontal plane which is comparatively constant is allowed for by a metal block from which the guide tongue juts out at the required angle. This block is pushed up firmly against the outer aspect of the trochanter, and carries the guide holes for the insertion of the Watson Jones guide. This method requires wider exposure of the parts than other methods.

The Hey-Groves Guide

This consists of a solid graduated square rod to which are attached (1) a short blunt upright fixed at the end ; (2) a movable pointed upright, slightly longer than the first ; (3) a director for the guide wire, which inserts it a fixed distance (equal to the radius of the femoral neck) below the pointed upright. In use the correct angle in the frontal plane is calculated from skin marking with clips, or the notched angle guide, or, if desired, the instrument can be used under the screen. Points on this line over the head and neck are marked, and the skin perforated with a sharp knife. The blunt point is then forced through the subcutaneous tissues and muscles till it is in contact with the head of the femur, and the pointed upright likewise in contact with the neck of the femur. The guide piece is then attached, and an incision made over the great trochanter so that it can be pushed into contact with the bone, and a Watson-Jones guide inserted. This method is accurate if the anterior surface of the neck of the femur is reasonably smooth, *i.e.*, the fracture has been reduced satisfactorily, and there are *no displaced fragments* of bone.

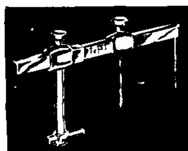


Fig. 510. The Hey-Groves guide for accurate insertion of the guide wire.

The Engel-May Guide

The principle of this guide is the use of a calibrated sector, attached by a pin to the femur, in such a manner that it may be turned from the frontal to the transverse plane, and so guide the insertion of the wire in both planes. The construction of the guide can be seen in the illustrations. A wedge-shaped sector is canalised with converging square holes, between which lie ribs of X-ray opaque material. There are a double row of canals to obviate the difficulty which would arise if the attaching pin corresponds to the desired



FIG. 507. The final position of an ideal pin,



FIG. 508. The final position of the pin in the lateral film.



FIG.

he femur has been
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arly weight bearing
es contact with the
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turned through 90° on the second pin, and fresh radiographs taken (Fig. 513). The correct angle in this plane is then read off, and the guide wire drilled down the appropriate canal. Correction has now been made for both angles of the



Fig. 512. The Engel-May guide as it appears in the A.P. radiograph. Note its attachment to the trochanter by the central pin.

femoral neck. The length of pin needed is calculated by simple proportion from the radiograph, the length of the Engel-May guide being known.

Many other names, Watson-Jones, Brittain, Gissane, Henderson, to



Fig. 513. The Engel-May guide in use. The guide lies at right angles to the position shown in the previous illustration, and is now ready for the radiograph showing the lateral view of the neck. (Left leg.)

mention only a few, are associated with developments in the use of various methods. An appeal to the list of references at the end of the chapter will allow of further information being found.

angle of insertion of the guide wire. The guide is attached by a square pin to the outer aspect of the great trochanter in a position as correct as it is possible to achieve from clinical judgment. A radiograph with the guide lying in the

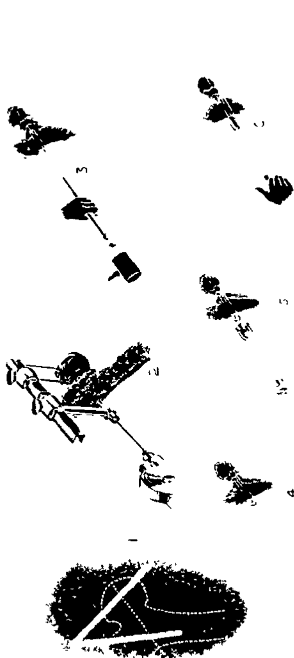


Fig. 511. The technique of using the Hey-Groves guide. 1. The use of a hinged gauge for calculating the angle of the neck in the frontal plane. 2. Showing the use of the guide which corrects for the deviation of head from the frontal plane. 3. *Driving the nail over the guide.* 4. *The nail driven home.* 5 and 6. The use of one variety of nail extractor.

frontal plane produces a picture similar to that of Fig. 512. From this it is easy to read off the canal corresponding to the central line of the femoral neck. A new square pin is inserted down this canal, and driven a short distance into the cortex by a smart hammer blow. The first pin is removed, the guide

turned through 90° on the second pin, and fresh radiographs taken (*Fig. 513*). The correct angle in this plane is then read off, and the guide wire drilled down the appropriate canal. Correction has now been made for both angles of the



Fig. 512. The Engel-May guide as it appears in the A.P. radiograph. Note its attachment to the trochanter by the central pin.

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mention only a few, are associated with developments in the use of various methods. An appeal to the list of references at the end of the chapter will allow of further information being found.

Technical Difficulties of the Nailing Operations

1. Failure to reduce the fracture. Unless a good anatomical position is achieved, nailing cannot be carried out satisfactorily. Under-reduction can be corrected by additional traction or manipulation. Over reduction is a more frequent cause of trouble, the head coming to lie in the "abducted" position over the neck. Relaxation of the traction does not always correct this as the fracture surfaces may interlock, or a spur of the calcar femorale be caught in the head. Re-manipulation must be tried and occasionally a pin in a less ideal position must be accepted.



Fig. 514. Breaking of the guide wire. In this case the fragment has been driven *into the joint, and arthrotomy was* necessary to remove it. Difficulties [illegible]

is not being [illegible]

2. Failure to get a satisfactory lateral radiograph *in the lateral view of a heavily built* patient. Abduct the legs further, and bring the tube nearer the plate.

[illegible]

[illegible] the head is entered by the nail, and is more common in younger subjects with harder femoral heads. In young subjects keep the nail a little more central on the femoral neck, and *directed more vertically. If not recognised this results in* bending the guide wire, which is then bitten into by the pin and carried further ahead. On attempting to withdraw it, it is found impossible, or the guide wire breaks, leaving a portion across the joint (Fig. 514). To avoid this, use smooth guide wires, never accept a position low in the head in the young, measure the length of the guide wire after hammering the nail part of the way in and watch it for advancement with the nail, and test the ability of the pin to rotate or withdraw. If it occurs, withdraw the nail first and then *withdraw the guide wire by tapping with a hammer on the introducer. Never attempt to withdraw the wire by twisting it.* This produces a shearing stress at the bend and almost inevitably breaks it.

4. Penetration of the guide wire. If a Kirschner wire bends it may be carried deeper into the tissues by the nail. In a similar manner the serrations on the Watson-Jones guide may catch on the point of the nail and so force it into the acetabulum. A pause must be made in hammering the nail, and the guide wire checked up for a decrease in the amount protruding.

5. Use of too long a nail. Allowance must be made for X-ray distortion, and for impaction in calculating the required length of nail. If the final radiograph shows it to be obtruding on the acetabulum it must be partly withdrawn. The use of a nail which is a little too long is much less serious than one which is too short. A small amount of protrusion of the nail seems to interfere very little with the function of the hip in the elderly. It cannot be permitted in the young.

6. Too short a nail. Reinsert the guide wire through the nail so that it penetrates sufficiently to get a good grip, withdraw the nail and insert a longer one.

THE JUDET ARTHROPLASTY

Because this method of treatment fulfils the demands made for treatment in elderly people, namely early mobilisation of the patient, and because of the complications which affect one-third of the cases which are nailed, it has been suggested that this procedure should become the routine procedure for subcapital fractures. Experience has shown that there are an equal number of complications affecting the Judet procedure, and that the best results of nailing are much better than the best results of a Judet. It cannot, therefore, be recommended as a routine treatment. It has been seen from the previous paragraphs that it is a very convenient procedure when certain complications are present, and their presence or the threat of them may justify the performance of a Judet arthroplasty as a primary procedure, though in general it is best used as a secondary one.



Fig. 515. The replacement of a fractured femoral neck with a metallic Judet type of prosthesis.

Complications justifying it may be :—

1. High fracture with delay in treatment and threat of avascular necrosis.
2. Delay in instituting treatment, with risk of non-union.
3. Osteoarthritis of the affected hip.
4. Avascular necrosis.
5. Established non-union in the older patient.

The operation where there has to be no preparation of the acetabulum for the femoral false head does not take long and is quite well tolerated by elderly patients. The approach recommended is a postero-lateral one (Gibson's). The head is removed, the femoral neck drilled and shaped and the head hammered home. The metallic head is less liable to fracture than the plastic one and its use is recommended. Exercises can be commenced according to the same routine used for a well-pinned fracture.

Complications of Subcapital Fracture of the Femoral Neck

Avascular necrosis of the femoral head. The blood supply is dependent on the artery to the ligamentum teres which plays a small part, the branches of the nutrient artery of the femur, and most important on three vessels which run along the surface of the neck to enter the head where it expands from the neck. It is these vessels which may be damaged in fracture of the femoral neck. Strangely enough the risk of damage is greater in the young than in the old, as it requires greater force to fracture the femoral neck of the young and so the arteries lying in the retinaculæ are more likely to be torn or compressed.



Fig. 516. Avascular necrosis of the femoral head in a young subject. The head is unaffected by the combined post-traumatic and disuse atrophy well seen in the femoral trochanter.

If all three vessels are torn then complete avascular necrosis of the head is inevitable. This is shown by a progressively increasing density of the head compared with the surrounding bones, which have undergone disuse atrophy (see Fig. 516). This may not be noticeable till a month or six weeks have passed. Later on the head may become very dense due to calcification (Fig. 521). The fracture fails to unite. In the past there was little that could be done for this serious complication. The patient was given a weight-relieving calliper, or possibly a McMurray osteotomy was done. The outlook has been greatly improved by the development of Judet arthroplasty in which it is possible to replace the femoral head with a plastic or metal head. This is the best answer to the problem.



FIG. 517. Ununited fracture of the neck of the femur in the young.

If one or two of the vessels is torn, then a partial avascular necrosis of the head will occur. This will only be slowly manifested, particularly if one vessel only has been torn. It is therefore possible to get union of the neck, and later on the patchy decalcification of the head, some collapse and the development of a degenerative arthritis of the hip. The Judet arthroplasty provides a ready answer to this.

Non-union of the femoral neck. This is a complication which still occurs. It is due to :—

1. Inadequate fixation of the fracture, *e.g.*, following failure to diagnose it.
2. Disimpaction and separation of the fracture surfaces by the pin.
3. Inadequate fixation by the pin, due to technical faults.
4. Avascular necrosis of the head.

It is diagnosed by the ab-



FIG. 518. Repair of an ununited fracture of the femoral neck by the use of a Smith Petersen nail and bone graft.

This may be supported by evidence of displacement of the pin (Fig. 517).

The longer a subcapital fracture is left without fixation by a pin when it is displaced the lower the chances of successful union. In an elderly person a month may be taken as a limit beyond which union is unlikely. Seen at this stage either a calliper can be given or a Judet arthroplasty suggested.

In younger patients provided that complete immobilisation of the fracture is achieved, and the fixation is supplemented with a bone graft

union will occur even after non-union having been established for six months. A pin is inserted a little more horizontally than usual to allow a fibular or tibial graft to lie in the neck above. Weight bearing must be delayed. In older patients mobility is the aim, and this is provided by a Judet arthroplasty, which is consequently more often chosen.

Osteoarthritis of the hip. This may be present at the time of the fracture. There is a natural temptation to perform a Judet arthroplasty, and this will often be wise. The degree of arthritis and the patient's general condition will influence the choice.

The development of arthritis is a disappointing sequel to fracture of the femoral neck, and occurs in one third of the cases which survive beyond two years. It is due to a combination of :—

1. Partial avascular necrosis.
2. Damage to the femoral head, by the accident or the pin.
3. Altered lines of pressure in the joint.
4. A generalised osteoarthritis.

A choice in treatment will lie between the conservative, physio-



Fig. 519. Non-union of a fracture of the femoral neck, with extrusion of the nail.



Fig. 520. "Overdrive." *Extrusion of the pin on the articular surface of the femoral head due to absorption of the neck at the site of fracture, probably due to partial avascular necrosis.*

therapy and a weight-relieving calliper, or the more radical McMurray osteotomy or Judet arthroplasty.

FRACTURE OF THE NAIL. This rarely occurs from metallic flaws, or incorrect insertion of the nail, with early weight bearing.

EROSION OF THE NAIL. This process is due to ionisation. It results in loosening of the nail. Very occasionally with inferior alloys it may produce fracture of the nail. Nails of a special non-magnetic stainless steel must be used.



FIG. 521. Ununited fracture of the femoral neck. Old fracture on the right with a viable head and atrophied neck. More recent fracture on the left showing the avascular sclerosis of the head of the femur.

EXTRUSION OF THE NAIL. This occurs in an unexplainable fashion, even in correctly nailed cases. The forces of expulsion are considerable, and require a deeply buried cross pin to prevent their action. Providing the extrusion occurs after union, no harm is done and the nail can be easily removed.

COLLAPSE OF THE HEAD AND EXTRUSION OF THE NAIL ("over-drive"). This is a complication of partial or complete avascular necrosis (Fig. 520). Occasionally it is relatively pain free, and then the penetration of the pain into the floor of the acetabulum adds stability. If painful, removal of the pin and the substitution of a Judet head may be done.

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fractures is around the age of sixty-five, while pertrochanteric fractures are maximal around seventy-five. Local bruising and swelling around the great trochanter. The fracture is nearer the surface, so bruising may be palpated and seen.

4) Axis of rotation. Occasionally one can appreciate that rotation of the leg is not occurring at the hip joint but around a more lateral axis.



FIG. 522. Pertrochanteric fracture of the femur, with a long spicule involving the lesser trochanter running down the shaft. This shows well the usual coxa vara present.

Gross shortening. This indicates a marked coxa vara only possible with lateral fracture.

Treatment. The aim of treatment remains the same as in subcapital fractures, namely early mobilisation of the patient. As these fractures affect a group approximately ten years older, early ambulation is even more important. Fixation with a pin is insufficient as there is not sufficient bone left in the trochanter to steady

Summary of the Local Complications of Fractures of the Upper End of the Femur

Due to	Pertrochanteric fractures	Subcapital fractures
Accident	Comminution of calcar femorale.	Avascular necrosis: Partial. Complete.
Faults in operative technique.	Fracture of trochanter.	Disimpaction and tilting of head. Penetration and breaking of guide wire. Too long a nail. Too short a nail. Badly placed nail.
Fault in appliance.	Breaking of nail plate.	
Too early weight bearing.	Avulsion of the plate. Bending of nail.	Displacement of the head. Bone collapse and "overdrive."
Late complications.		Non-union. Osteo-arthritis. Extrusion of nail: With un-united fracture. With united fracture.

Results in Fracture of the Femoral Neck over Sixty

Successful	60 per cent.
Bony union but necrosis	7·5 " "
Bony union and "overdrive"	2·5 " "
Failed pinning, operative faults.	2·5 " "
Fibrous union	8 " "
Local suppuration	2·5 " "
Died within 4 months	7·5 " "
Doubtful end results	9·5 " "

Pertrochanteric Fractures

These fractures unite readily under correct treatment, and the difficulties with them depend on their association with an older age group than fractures of the neck, but are essentially the same. The fracture line is oblique, running from the trochanteric fossa to the medial aspect of the shaft either above or below the lesser trochanter. In some cases the fragments are comminuted, either or both trochanters separating. There is usually a coxa vara, which varies in degree, with gross eversion of the foot. A number of the fractures are firmly impacted, with the result that the physical signs are altered (see p. 467). It is not always possible to distinguish a pertrochanteric fracture from a subcapital fracture before the radiograph is inspected, but the following points may be of assistance.

The history of injury. In subcapital fracture this is often a simple external rotation strain of the foot, while in pertrochanteric fractures it is a fall on the hip.

The age of the patient. The maximum incidence of subcapital

fractures is around the age of sixty-five, while pertrochanteric fractures are maximal around seventy-five. Local bruising and swelling around the great trochanter. The fracture is nearer the surface, so bruising may be palpated *and seen.*

Axis of rotation. Occasionally one can appreciate that rotation of the leg *is not occurring* at the hip joint but around a more lateral axis.



FIG. 522. Pertrochanteric fracture of the femur, with a long spicule involving the lesser trochanter running down the shaft. This shows well the usual coxa vara present.

Gross shortening. This indicates a marked coxa vara only possible with lateral fracture.

Treatment. The aim of treatment remains the same as in subcapital fractures, namely early mobilisation of the patient. As these fractures affect a group approximately ten years older, early ambulation is even more important. Fixation with a pin is insufficient as there is not sufficient bone left in the trochanter to steady

the fracture. The addition of a plate to the pin taking the leverage from the femoral-shaft overcomes the difficulty. Early operation and early activity are the goal in the aged, and are best achieved by an immediate pin and plate operation. In adolescents and young men in whom operation is undesirable alternative methods of treatment may be applied, and these will be outlined.

If the fracture is firmly impacted and in good position, *i.e.*, very little coxa vara, it is possible to treat the fracture by continuous traction. This is necessary, for, if the pull of the pelvi-femoral *muscles is not opposed, an increasing coxa vara will develop.* This condition is, however, seldom encountered, as if the fracture is firmly impacted, it means the neck is driven into the trochanter, and there is inevitably a marked coxa vara. A coxa vara by interfering with [illegible] again. It must be avoided and this provides a further indication for operation.

Whether the fracture is impacted or unimpacted an operation should be carried out in the elderly, namely a pin and plate ; in the adult patient operation is also often indicated. In the young patient one of the alternative forms of closed treatment is the choice.

An outline of the course of treatment is thus essentially the same for an elderly patient as if there were a subcapital fracture, except that the incision must be a little longer, as a plate is to be inserted, but this is counterbalanced by the greater simplicity in introducing *the pin which need not be so accurately placed.*

The patient is admitted, put in bed and skeletal traction applied through the tibial tuberosity. This steadies the fracture, corrects the eversion of the foot, and relieves pain. Occasionally it may be omitted with impacted fractures where the leg is comfortable, and only needs the support of sand bags. Having assessed the general condition of the patient a decision to operate is made wherever possible. Failure to fix the fracture is often a death warrant in the aged as the long period of bed nursing frequently leads to fatal complications. The operative technique is similar, radiological control being used to place the pin in position, the exact procedure depending on the type of pin and plate used. The return to bed is followed by early mobilisation of the patient in whom with an uncomminuted fracture and intact calcar femorale almost immediate weight bearing is possible The patient's progress should be equally rapid, as with a subcapital fracture and the average stay in hospital should be four to six weeks. The complications encountered are *similar to those affecting the simple pinning procedure, but owing to* the good blood supply there is never any fear of avascular necrosis

or of non-union. Mal-union with coxa vara is the commonest error.

Types of pin and plate. These are many and fall into two main groups :—

1. Those in which the angle between the pin and plate is variable.
2. Those in which the angle is fixed.

Where the angle is variable such as in the McLaughlin nail-plate (Fig. 523) a weak point is inevitably introduced between the plate



Fig. 523. A pertrochanteric fracture fixed by a McLaughlin nail and plate.



Fig 524. Avulsion of a plate in spite of adequate screw length, in an elderly osteoporotic patient.

and pin. In this case fixation is by a screw, and this has been modified to improve its grip. The angle is always a weak point even in the fixed nail and plate, and for early weight bearing rigid appliances should be chosen. They require some form of template for the insertion of the guide wire at the correct angle if the plate is to lie along the shaft satisfactorily, but some of them are so arranged that the plate may be bent to correct the last few degrees of angulation (Fig. 526). In attaching the plate to the femur the screws should [illegible]

[illegible]

Alternative non-operative methods of treatment

Continuous traction. This commenced with skeletal traction through the tibial tuberosity and with the leg supported on a Braun's

splint or Thomas splint. This may be bent at the knee or a Pearson's knee flexion attachment used. A heavy pull through the knee is undesirable for any length of time, and it is often wise to change this to traction through the lower end of the femur after ten days, though there is some additional risk of pin tack infection if the knee is exercised. In a young patient a change to fixed distraction on a Thomas splint using skin traction and a Tobruk plaster (Figs. 549 and 550) may be made at the end of four weeks.

Fixed distraction. Having reduced the fracture by manipulation or by skeletal traction on a Hawley table, with the assistance of a check X-ray, the reduction may be retained by one of the following methods.

1. A Whitman's plaster including the opposite leg to the knee. This is a heavy plaster, and the pelvis may tilt in it, permitting the recurrence of a coxa vara. It must therefore be carefully watched.
2. A Thomas splint with fixed skin traction (Fig. 135) reinforced with a plaster over it, in the manner of a Tobruk splint, and a pull applied to the end of the Thomas splint.
3. A Thomas splint with the Kirschner wire through the tibial tuberosity included in the Tobruk plaster surrounding it. Traction may then be continued on the wire to relieve pressure on the ring of the Thomas. This method, because of its reliability has much to recommend it.

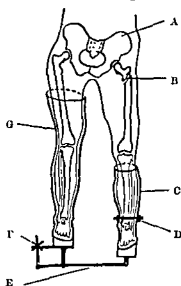


Fig. 525. The well-leg traction-splint A. Pelvis, tilted on the injured side B. Pertrochanteric fracture. C. Short plaster below the knee including the pin inserted through the lower end of the tibia D. Steinmann's pin. E. Hinged cross bar. F. Tightening screw. G. Long thigh plaster to fix knee on the unaffected side. The fulcrum of the lever is firmly attached to the sole of this plaster.

The well-leg traction splint. The principle of this splint depends on turning the sound leg into a solid rod by a plaster applied from the thigh down to the toes. By incorporating a swivel at the foot to which a lever is fixed, and attaching the other end of this to the injured limb by means of a pin in the lower end of the tibia, extension can be applied to the injured limb. The pelvis tilts first so that the sound leg is adducted and the injured leg is abducted. When this reaches a maximum the injured leg is extended. The fracture is thus adequately reduced and immobilised. The advantage of the

apparatus is that the patient can be easily moved, and can sit up immediately. Its disadvantages are the fixation of both knees and the development of pressure points in the plaster. It is not used extensively.

Fractures of the great trochanter. In the young, fractures tend to occur at the epiphyseal line. They may be due to direct violence or to the pull of the gluteus medius and the gluteus *minimus*. In adults the fracture is more commonly combined with a pertrochanteric fracture. Characteristically there is local pain and *swelling, but the patient can put the affec*
is, however,
from the floor. The displacement is as a rule small, and requires no reduction, but if marked the leg is treated in full abduction. Union is rapid and there is no disability.

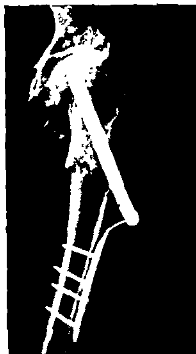


Fig. 526. Trifin nail and plate for subtrochanteric and pertrochanteric features. (G. K. McKee.)

Fractures of the lesser trochanter. These are due to the muscular pull of the ilio-psoas, and in the young take the form of an epiphyseal separation. Ninety per cent. of the cases occur in adolescence. The patient is characteristically unable to flex the thigh further when in a *sitting* position. There is local pain and bruising, and pain on *hyper-extension of the thigh.* The fragment is displaced upwards and the only possibility of reducing it is to flex the leg. This may be maintained by a plaster spica. Unless the displacement is gross this is not worth while, the fragment uniting rapidly and producing no disability (Figs. 527 and 528).

Separation of the epiphysis for the head of the femur. It is necessary to include the description of this lesion here because of its undoubted association with trauma. Cases may be divided into the following groups.

1. With a story of pain in the hip over a long period, followed by *the development of a limp.*

2. Story of pain over a period followed by pronounced symptoms after *moderate injury, or slight injury.*

3. No story of pain, the condition occurring suddenly as the result of severe trauma.

The last type of case is the most uncommon, and it can be



FIG. 527. Avulsion of the secondary centre for attachment of the ilio-psoas.



FIG. 528. View of the opposite limb for comparison.

debated, whether this lesion is not similar to the others, *i.e.*, the end result of a series of changes in the neck of the femur of developmental, endocrinal, or metabolic origin, rather than entirely traumatic. In the cases of slower development there is a frequently associated adiposity, and under-development of the sexual characteristics. It occurs more commonly in males (five to two) at the adolescent period. A small percentage of the cases are bilateral.

Diagnosis. Acute cases resemble fracture of the neck of the femur, suspicion being aroused by the patient's age. The A.P. radiograph shows the head displaced downwards, so that the upper margin of the neck is continuous with the head of the femur, and the head forms a sickle-shaped protuberance on the lower side of the neck, which thus no longer shows the smooth curve continuous with the curve of the upper margin of the obturator foramen. (Shenton's line.) In subacute cases callus may be seen on the under surface of the neck. The changes in the head seen in Perthes' disease do not occur. In later years the hip may develop osteo-arthritis.

Treatment. *The province of this book is trauma, and it is proof* of recent acute traumatic separation of the epiphysis if it can be reduced, by either manipulation or continuous traction. Such epiphyses will be widely displaced. In the more common slow slip, the displacement may be small and the epiphysis will be uninfluenced by traction or manipulation. In these circumstances the deformity if slight can be accepted, and further shift stopped with a Smith-Petersen pin. If the deformity is too great to be accepted then the only recourse is open operation, wedge resection of the neck and fixation with a trifin nail.

If after manipulation a satisfactory position of the head is achieved this may be fixed by a trifin nail, or fixation by one of the non-operative methods outlined on p. 491 may be used. If this is done the use of a protective walking calliper for some time afterwards is advisable. Owing to the fact that inversion of the foot produces apparent reduction in the radiograph, the importance of lateral films to establish complete reduction must be emphasised.

Fractures of the Shaft of the Femur

This, the largest long bone in the body, is subject to fractures of the same varieties as the other long bones, transverse, oblique and comminuted, with the disabilities attendant on each one. It combines with these, however, difficulties peculiar to itself, which are due largely to the huge muscle bulk surrounding the bone.

1. The large hæmatoma distends the fascial envelope of the thigh and prevents extension being effective for the first few days.

2. The muscle bulk prevents control of the fractured ends of the bones by lateral splintage for the first few weeks.

3. When the thigh has wasted from disuse, and only then, is plaster an effective method of control of the fracture.

4. The pull of the ilio-psoas flexes fractures of the upper third of the femur, and demands special efforts to correct it.

5. The pull of the gastrocnemii flexes fractures of the femoral condyles, and requires flexion of the knee or operative fixation to correct it.

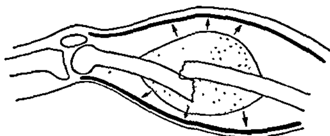


FIG. 529. Distension of the inelastic fascial envelope of the thigh by blood prevents reduction of a fracture of the femur. (After Charnley.)

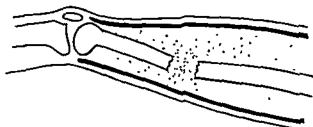


FIG 530. After dispersion of the hæmotoma and wasting of the thigh muscles, over-extension is readily produced by the same weight.

The fracturing of such a heavy bone requires great violence, and so injuries to the soft tissues are common and may interfere with treatment. The displacements of the bone ends from the force, the spasm of muscle and leverage of the leg may be very great, and tend to produce a large hæmatoma in the quadriceps with later fibrosis and stiffness of the knee. To maintain reduction against the muscle tone, which differs from the tone in muscles elsewhere in being of postural origin, requires considerable weight, with the resultant risk of over-extension and non-union. Any attempt to produce correction of the lateral or antero-posterior displacement of the fragments by pressure pads is offset by the cushioning actions of the muscles and fat which are displaced more than the bone ends. In young patients these difficulties are minimal, in old, fat patients they may be almost insurmountable.

The fracturing force may be direct or indirect. The main displacement in all cases is shortening, but in fractures high in the shaft



Fig. 531. Slipped femoral epiphysis. been restored. The epiphysis o sickle-shaped projection of the sh line can be seen, more marked on the left than the right.



Fig. 532. Same case as in previous figure after skeletal traction with the legs abducted. The head is restored to almost normal position, and Shenton's line reconstituted. For complete confirmation of this a lateral radiograph is required.

the pull of the ilio-psoas is more effective, and flexes the upper fragment, while in fracture in the lower third the tension of the gastrocnemius tends to rotate the lower fragment posteriorly.

Diagnosis. These cases present all the classical features of

2. The muscle bulk prevents control of the fractured ends of the bones by lateral splintage for the first few weeks.

3. When the thigh has wasted from disuse, and only then, is plaster an effective method of control of the fracture.

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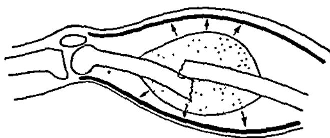


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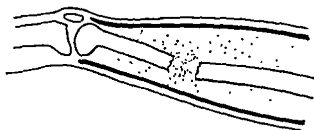


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The fracturing force may be direct or indirect. The main displacement in all cases is shortening, but in fractures high in the shaft

gotten. Shock may be severe in old people, and novocaine infiltration is easy and particularly effective in these cases.

If continuous or fixed traction is to be employed the use of a skeleton splint to support the leg is necessary. Either the Thomas splint or the Braun's splint may be employed. The Thomas splint is more adaptable, and may be used straight, with the end attached to the foot rail of the bed or slung from pulleys from an overhead beam of a Balkan frame or a Pearson's bed. The slung Thomas is to be recommended for general use, as it allows the patient much greater freedom of movement in bed without disturbing the fracture ;



FIG. 533. Fracture of the femur treated by skeletal traction in the femur, and skin traction on the leg, supported on a Thomas splint with knee flexion piece.

and, as he recovers, a far greater range of exercises. The Thomas splint may be employed bent at the knee or with a knee flexion piece, if flexion at the knee is desirable.

Traction. This in itself is insufficient to immobilise any fracture of the femur, however strongly it is applied. In all compound fractures its use alone is to be avoided, except as an aid to reduction and stability at the time of operation. It has the further disadvantage of tending to over-distract, and of damaging the knee by ligamentous tension if retained too long. It is obvious that traction cannot be exerted on the ligaments when the shaft is broken and that all traction is opposed by the muscles. Only when there is some bony or strong fibrous adhesions does the traction pull through the ligaments of the knee (Figs. 534, 535). If the fracture is accompanied by a large hæmatoma and the fascial sheath of the thigh is distended traction of any kind is ineffective in the first few days.

fracture, often in an acute form, and no difficulty is given except in the case of an incomplete fracture of the shaft, or fracture of a process. In these cases following injury there is persistent pain in the thigh followed by bruising, but there is little swelling. An X-ray in one plane may overlook the fracture, which may be oblique or spiral. An X-ray in both planes will generally demonstrate the lesion, and is essential in all cases.

Fractures of the shaft of the femur fall into three great groups, each presenting particular difficulties. These are :—

1. Fractures of the shaft of the bone in the middle third.
2. Fractures of the upper third of the shaft (subtrochanteric fractures).
3. Fractures of the lower third of the shaft.

Spiral or oblique fractures at these levels seldom cause trouble. It is the displaced transverse fracture or comminuted fracture which is so difficult to control.

It will be convenient to discuss the general methods of treatment which are available first, as these may be applicable to fractures in all three sites, and then the special treatment available for fractures of the upper and lower thirds which present peculiar difficulties.

Methods of Treatment of Fractures of the Shaft of the Femur

1. Fixed traction.
2. Continuous traction.
3. Manipulative reduction and plaster fixation.
4. Open operation and fixation
5. Combination of these methods.

All these methods have a place in treatment. We may commence by saying that as an emergency measure treatment by traction is most satisfactory as it requires little disturbance, and does not increase the shock. Under intravenous anæsthesia a wire is inserted in the tibial tuberosity or the lower end of the femur. Unless the fracture is in the lower third of the femur a pin above the knee may be preferred for the same reasons as govern the choice of that site in pertrochanteric fractures. The risk of infecting the hæmatoma in fractures of the lower third is too great for a pin or wire to be used.

Preliminary treatment by light traction is to be recommended whether it is to be continued or not, as it allows time for the swelling to subside, time for recovery from shock and for accurate diagnosis and deliberation. In combating the shock of the original injury the value of novocaine injected into the hæmatoma is not to be for-

FIXED TRACTION. The method of fixed traction as devised by H. O. Thomas has been undesirably abused by the partisans of skeletal traction. The principle of the method has been misunderstood, and it has been considered as a method of reduction rather than a method of retention. It is a method of fixation, in which the force

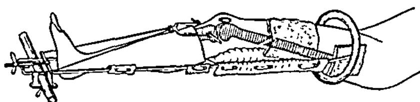


FIG. 537. Method of retaining a fracture of the femur in position, using a skeletal pin and fixed traction. A plaster may be used at the same time to control a fracture of the leg. (After Charnley.)

of muscular contraction tending to shorten the leg at the site of fracture is opposed by the fixation of the leg (by skin traction in the original method, but often by skeletal traction nowadays) to the lower end of the splint, and of the counter-pressure exerted by the ring of the Thomas splint on the ischial tuberosity. In a closed system like this only the tone in the muscles can be responsible for maintaining tension, and the resultant pressure on the ring of the Thomas splint cannot be excessive. It may be diminished by

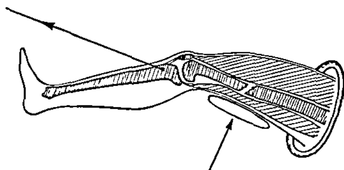


FIG. 538. Traction on the leg in a Braun's frame or Thomas splint with knee flexion piece. Forces incorrectly balanced. Pad placed under fracture and not below. Traction in the line of the femur must be balanced by traction on the leg in the line of the tibia as in Fig. 544, when the Braun's splint is used—or as in Fig. 536 when a Thomas splint is used.

elevating the foot of the bed or placing traction on the lower end of the Thomas splint. It is, however, insufficient to rely on two-point suspension of the limb to produce stability, and a third force must be employed. This is provided by a large pad behind the knee, which by flexing the knee against gravity and muscle tension, stabilises the system (Fig. 536). It is, however, essential if fixed traction is to be effective that the fracture be reduced first. If the

As the hæmatoma resolves it becomes effective in separating the bone ends and, as the muscles of the thigh waste, more effective through lack of opposition (Fig. 530). It is obvious that gradual

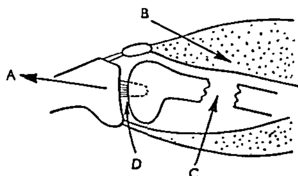


FIG. 534. Traction on the tibia in the early stages does not produce traction on the ligaments of the knee joint but separates the fracture. A. Direction of traction. B. Fully developed quadriceps. C. Fracture hæmatoma. D. Joint space. (After Charnley.)

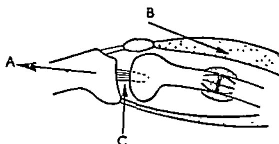


FIG. 535. When the fracture has united and the muscles wasted, traction produces a pull on the ligaments of the knee joint. A. Direction of traction B. Wasted quadriceps. C. Increased joint space

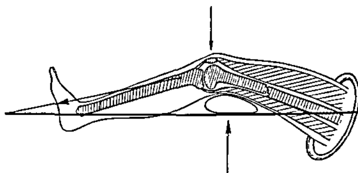


FIG. 536 Traction on the leg in a Thomas splint. The correct arrangement of forces Note how the pad behind the knee produces a stable triangulation of forces as well as maintaining the anterior bowing of the femur.

reduction of the fracture by continuous traction is the only satisfactory method of treating such cases. If fixed traction is used it is ineffective to begin with, and when the hæmatoma has sufficiently diminished soft tissue adhesions may make restoration of full length difficult.

Fixed traction. The method of fixed traction as devised by H. O. Thomas has been undesirably abused by the partisans of skeletal traction. The principle of the method has been misunderstood, and it has been considered as a method of reduction rather than a method of retention. It is a method of fixation, in which the force

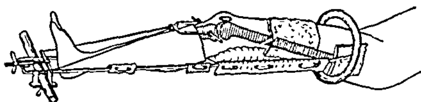


Fig. 537. Method of retaining a fracture of the femur in position, using a skeletal pin and fixed traction. A plaster may be used at the same time to control a fracture of the leg. (After Charnley.)

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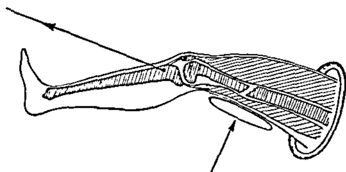


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FIG. 539. Fracture of the shaft of the femur in a late stage under skin traction with Unna's paste. Traction applied in the direction of the femoral shaft of the leg. Stockinette over the foot with a weight attached is used to prevent foot drop.

thigh is distended with blood this is impossible in the first few days and treatment with continuous traction is indicated. If reduction is possible the reduced femur is put up by fixed traction and then should maintain itself, with but slight adjustments. (Compare application of fixed traction in Tobruk plasters, p. 509).



FIG. 540. Same case as in the previous figure, but with the Braun's splint removed for exercises over the knee exercise bar.

Continuous Traction. The elaboration of continuous traction is due to the development of skeletal traction, as the forces employed are more than skin traction can support For satisfactory continuous traction a resultant force in the line of the femur must be generated, and this necessitates flexing the knee. This may be accomplished on the Braun's frame, on the Thomas splint bent at

the knee, or provided with a knee flexion piece, or by the Hamilton Russell method.

It is an unstable system until a third force has been introduced. In the case of the Braun's splint this is provided by skin traction on the leg, which flexes the thigh over a pad above the knee (Fig. 544). A similar pad may be used on the bent Thomas splint. In the Hamilton Russell method the pad behind the knee and the pull on the leg make the system fairly stable if the leg is not excessively flexed (Fig. 549). The disadvantage of the Braun's frame is the lack of fixation of the upper end of the thigh, which is also to be noted in



FIG. 541. Oblique fracture of the femur showing its position on a Braun's splint under skeletal traction.

the Hamilton Russell method. The patient is thus afraid to move for fear of hurting himself in the early stages, with increased nursing difficulties, or in the later stages when the fracture is painless is continually altering his alignment. The Thomas splint thus has advantages, if continuous traction is used, over other splints. If slung from the bed and properly balanced it enables the patient to move freely with little disturbance of the fracture. In continuous traction the splint is used as a cradle only and ring pressure should not occur. It is necessary, however, to make sure that it remains in contact with the tuberosity of the ischium by having the pull of the cord supporting the upper end of the splint running obliquely towards the upper end of the bed.

The forces engaged in the system are governed by the weights applied, and excite a corresponding tension in the muscles and soft tissues around the fracture site. To commence with they may be exerted in compressing the hæmatoma in the muscles if this is large. As it subsides the pull is opposed by the muscles, and finally as these

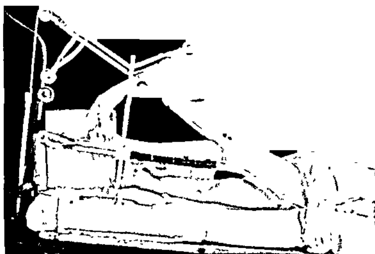


FIG. 539. Fracture of the shaft of the femur in a late stage under skin traction with Unna's paste. Traction applied in the direction of the femoral shaft of the leg. Stockinette over the foot with a weight attached is used to prevent foot drop.

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Continuous Traction. The *elaboration of continuous* traction is due to the development of skeletal traction, as the forces employed are more than skin traction can support. For satisfactory continuous traction a resultant force in the line of the femur must be generated, and this necessitates flexing the knee. This may be accomplished on the Braun's frame, on the Thomas splint bent at

subsequent immobilisation will be much less serious in its consequences. Active concentration on the quadriceps and movement of the knee should therefore be encouraged in all methods from the earliest possible moment. In the early stages faradism may help. In the later stages knee bending exercises over a bar may be employed in patients in whom there is some doubt as to the strength *of union.*

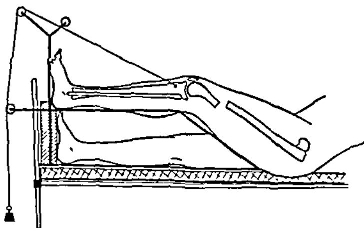


Fig. 543. *Backward displacement of the lower end of the femur from incorrect positioning of the Braun's splint.*

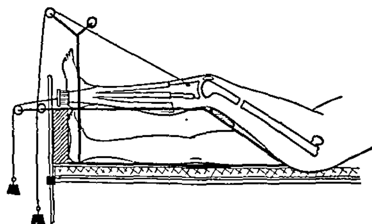


Fig. 544. The displac moving the angle traction on the leg

Although there is no doubt that there is an earlier return of function if the quadriceps is exercised, the final degree of flexion of the knee is largely determined by the amount of damage to the quadriceps at the original injury Thus given an equivalent injury, at the end of two years the degree of flexion of the knee will be the same, whether it has been treated by quadriceps exercises early or not, the sole difference will be that the case exercised early will achieve maximum flexion sooner than the other. These considerations do not hold in the elderly patient with an osteo-arthritic knee,

waste, and the soft tissues around the bones become more organised, the pull is transmitted through the ligaments and bone of the limb. It follows that with all these variable factors the weight employed has to be carefully calculated and continually adjusted. If no hæmatoma is present, due perhaps to the wound being an open one, a weight of 10 lbs. may be sufficient from the beginning. On the other hand, in a powerful thigh a weight of 20 to 30 lbs. may be

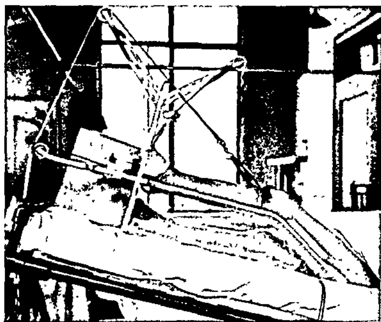


FIG. 542. Fracture of the shaft of the femur under skeletal traction in the tuberosity of the tibia, combined with skin traction on the leg.

necessary to prevent shortening, and this must be reduced over the first three weeks to 10 to 12 lbs. if overdistraction is not to occur.

Satisfactory results may be achieved by either method in experienced hands. While fixed traction corresponds to the ideal of complete immobilisation, and is therefore more satisfactory for compound fractures, with continuous traction earlier concentration on the quadriceps tone and exercise of the knee joint are possible. *The success of treatment of a fractured femur is primarily to be gauged by the function of the knee, and secondarily by the position obtained. There is no evidence to show that early movement of the knee joint delays union of the femur, though the movement at the fracture site in an energetic patient is sometimes alarming. It is certain, however, that the adhesions which form a serious block to movement form in the first six weeks, and it is during this period that active use of the quadriceps should be encouraged.* If a small free range of knee joint movement has been preserved for this period,

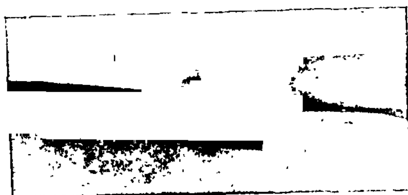


Fig. 545. Comminuted fracture of the shaft of the femur, with displacement.

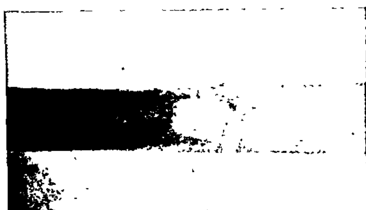


Fig. 546. Antero-posterior view of the previous case under treatment, showing satisfactory position under traction.

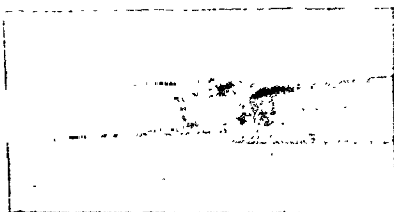


Fig. 547. Lateral view of the same case showing the satisfactory position in both planes.

Some nails are slightly curved at either end to facilitate their introduction. The nail is introduced through the sites of easy approach to the marrow, such as the radial styloid, the greater tuberosity of the humerus, the great trochanter, and the tibial tuberosity.

There are two methods of using the nail; either reduction can be

in which long fixation is disastrous, and in whom concessions must be made to early exercise.

Manipulative reduction and plaster fixation. The fixation provided by plaster is ideal for compound fractures, in which steady immobilisation of the fracture and surrounding tissue planes is necessary. The only plaster fixing the hip and femur thoroughly is the hip spica, and this is a heavy plaster taking time and effort to apply. It is much easier and more comfortable for the patient to use the Tobruk plaster described later.

In children who are too old to be slung up by Bryant's method, and in whom stiffness is unlikely to occur, the early applications of a plaster spica in which they can get about on crutches is valuable.

Open operation and fixation. This method has the advantages of any operative method of treatment, perfect reduction, and early function. In the femur there is a disadvantage which cannot be entirely overcome, namely, the weight of metal which must be inserted, and the subsequent adhesions of the quadriceps when this is done through a wide approach. Perfect reduction is not so important if the line of the femur can be maintained. It is thus particularly in angular deformities and in transverse fractures with overlap that operation is called for.

Types of operation

PIN AND PLATE. In subtrochanteric fractures with displacement, and in those subtrochanteric fractures with flexion of the upper fragments due to the pull of the ilio-psoas, the conditions are very similar to those of a pertrochanteric fracture. Although the reduction is a little more difficult the retention by a pin and plate is equally satisfactory and is the recommended method of treatment.

PLATE AND SCREWS. This is used for transverse or comminuted fractures It requires wide separation of the muscles for its insertion through an anterior approach (see p 694) and a little less serious damage when a lateral approach is used. The ideal approach to avoid adhesions of the quadriceps is a posterior approach, and if fixation of the central half of the femur must be carried out by a plate this approach is best.

ROGER ANDERSON SPLINT (see p. 492).

KUNTSCHER'S INTRAMEDULLARY NAIL. The use of a larger diameter intramedullary nail is a logical extension of the intramedullary Kirschner wire, and was first employed by Kuntscher in 1941. Its introduction to German surgeons was at first unfavourable, and there are still sharp divisions on its uses and value. The nail, modified by various surgeons, consists of a metallic rod of varying length, triangular or diamond-shaped, or even circular on section.

There is a slight risk of fat embolism in elderly people. Technical difficulties may arise from fracture of the nail, bending of the nail, penetration of the cortex, and distraction of the fragments. The strength of union is difficult to gauge with the nail in position.

Experience with the nail suggests that it is a useful addition to the surgical armoury for certain fractures, notably the transverse fractures of the shaft of the femur, with deformity. The difficult fracture below the lesser trochanter, with cocking up of the short proximal fragment, is easily controlled. The nearer the fracture to the knee, the less suitable the method. Although it requires exposure of the fracture for its insertion there need not be such wide stripping of muscles, so fewer quadriceps adhesions. In open fractures it can be readily inserted, and this should add little to the risk of infection, while if there are soft tissue injuries such as skin loss the stabilisation of the fracture is very helpful.

COMBINED METHODS. It is possible to combine the methods described in many ways ; thus a hip spica may include a transfixion pin through the femur or the tibial tuberosity. Alternatively the pins may be attached by clamps to the side bars of the splint, a proceeding which facilitates inspection of the skin and thus may be useful in combined fractures and burns. In practice a combination of the Thomas splint and plaster, known as the Tobruk plaster, covers most eventualities and is comparatively simple. The limb can be attached to the Thomas by skin traction, or the wire or pin through the tibia incorporated in the plaster, thus providing fixed distraction. It is particularly in compound fractures and for cases which have to be transported that it is useful.

THE TOBRUK PLASTER, AND MODIFICATIONS. After adequate toilet of the wound, skin traction is applied by one-way stretch Elastoplast, pads being placed over the malleoli. Stockinette and cotton wool or stockinette alone may be placed over the leg to prevent adhesion of the plaster to the strapping. The leg is then placed on a Thomas splint in the ordinary manner. The slings being in position, a large pad of cotton wool, 8 inches by 6 inches by 3 inches, is placed behind the knee. Care is taken in the case of anterior wounds to see that the slings are tight and that the whole leg lies well in front of the bars of the Thomas splint. This enables inspection of anterior wounds to be carried out subsequently without the bars obscuring the sides of the limb. If the wound is a posterior one the limb may be allowed to fall through the bars to some extent to facilitate inspection of the posterior aspect of the limb. The fracture is then set in as satisfactory a position as is possible by traction and adjustment of the pad and sling, and the traction tapes tied firmly around the lower end of the splint. If a large ring

accomplished manually, and with or without the assistance of radiography the nail can be slid across the fracture site, or open reduction of the fracture can be carried out, and the nail slid across the fracture *under direct vision* ; *this entailing a separate incision for its introduction.* For its effective use a good selection of nails is necessary



a b c

FIG

FIG. ... the fracture.

FIG. 548c Healing of the fracture with the Kuntscher nail still in position, showing well-organised deposits of sub-periosteal new bone.

varying in both length and diameter, as it is essential that the nail should grip the medullary cavity without jamming. A nail one millimetre smaller than the diameter of the medullary cavity is chosen. Skeletal traction may be used to reduce the fracture, and some surgeons prefer to use screening. In the tibia and the femur a guide may be used to facilitate the introduction of the nail. Accurate reduction of the fracture, is the primary basis of easy and successful nailing. External support of some type is employed in most cases.

(Fig. 551) so that the side bars are included in a plaster U and the cross-section of the limb resembles a ball of plasticine pinched out on each side. To do this the plaster must be left slack anteriorly. It is then well moulded around the limb as it sets.

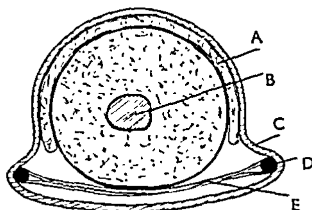


FIG. 551. Section of the femur lying in a transport plaster.
A. Cotton wool pad.
B. Femur.
C. Plaster.
D. Side bar of Thomas splint.
E. Sling.

It is important that the foot be held at right angles to the limb and that the toes be protected from the weight of the blankets. If the leg has been enclosed in a short plaster for other injuries the plaster should extend beyond the toes. This will provide sufficient support. If the leg is uninjured a Thomas footpiece is strapped on

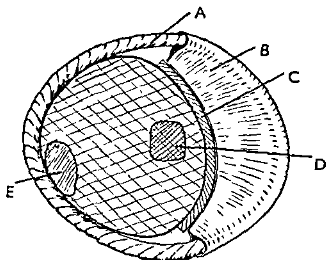


FIG. 552. Section of Thomas splint at plane of ring showing one method of narrowing the ring of the splint to obtain a better fit.
A. Ring of splint.
B. Folded over plaster slab.
C. Felt strip on skin over trochanter.
D. Section of trochanter.
E. Ischial protuberance.

Thomas splint is being used, difficulty may be met with, as it rides off the ischium and presses on the perineum. This may even cause retention of urine, a serious disability during transport. To offset this the diameter of the ring may be decreased by one of two methods :—

(*a*) It may be filled with a large pad made of cotton wool wrapped in a few turns of plaster. The plaster must not be sufficiently thick to make a hard surface on setting and is used merely as a covering. This pad is placed

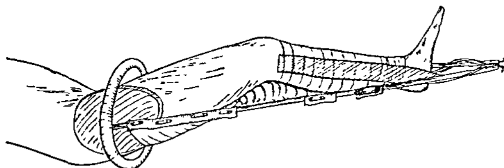


Fig. 549. A fracture of the femur lying in slings in a Thomas splint. Note pad over trochanter to decrease the diameter of the ring of the splint, pad behind knee and the skin traction on the leg. In the case of an associated fracture of the leg ; this can be replaced by a short padded leg plaster.

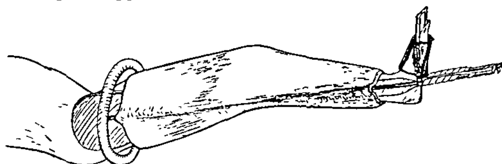


Fig. 550 The complete transport plaster—a modified "Tobruk" type The leg, as shown in Fig 549, is covered with a layer of wool before the application of the plaster. Note the pinching in of the plaster (Fig. 551) on either side The foot is supported by a plaster cuff.

between the trochanter and ilium and the ring of the splint. It moulds itself to the tissues and the ring and so does not slip out or alter its position, the setting of plaster assisting in retaining it in place.

(*b*) A felt pad may be placed over the trochanter and outer part of the thigh. A plaster slab 15 to 20 inches in length is then placed over the outer portion of the ring and split opposite the side bar of the Thomas splint. It is then moulded over the ring on both sides so that it fills the gap between the ring and the felt (Fig. 552).

Having fixed the limb firmly on the splint the front of the thigh, knee and leg is padded with cotton wool. The whole limb and splint is then enclosed in plaster which is moulded in at either side

(Fig. 551) so that the side bars are included in a plaster U and the cross-section of the limb resembles a ball of plasticine pinched out on each side. To do this the plaster must be left slack anteriorly. It is then well moulded around the limb as it sets.

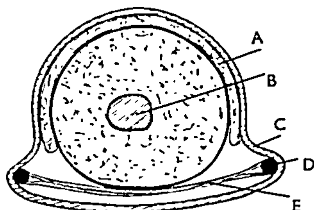


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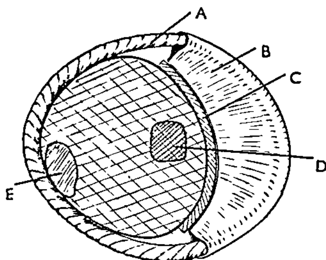


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A. Ring of splint.
B. Folded over plaster slab.
C. Felt strip on skin over trochanter.
D. Section of trochanter.
E. Ischial protuberance.

to the splint. This should be high enough to take the pressure of the blankets off the toes. A piece of gamgee is placed on either side of the foot and the gamgee, foot, and side bars of the footpiece incorporated in a few circular turns of plaster. In other words, the foot is maintained in dorsiflexion by a similar means to that used for fixing the limb.

At the end of the proceeding brief diagrammatic and written notes of the injury and its treatment should be recorded in indelible pencil on the plaster.

THE HIP. Immobilisation of injuries in the region of the hip joint is difficult to carry out satisfactorily. The plaster spica is unsatisfactory for reasons previously given. A useful temporary method for transport is provided by the abduction frame for the hip. This enables rapid fixation of injured lower limbs and so shortens operating time. It may be invaluable for transport or for fractures of the femur complicated by other injuries. Various combinations of traction on the lower limb and plaster may be used with it.

Deformities arising in the Treatment of Fractures of the Femoral Shaft

The deformities are to some extent dependent on the shape of the fracture, and these have been outlined before (p. 34). The shaft tends to sink backwards if not supported, its marked anterior curve being forgotten in padding the splint. Similarly if weight bearing is commenced too soon the bone tends to bow forwards and outwards. SHORTENING, the chief difficulty, has been already dealt with.

ROTATION. There is a tendency for the upper fragment to be externally rotated. This can be checked by radiographs of the neck of the femur and comparison of position of the inter-trochanteric line on the two sides (Figs. 495, 496). The position of the foot can then be arranged to correspond to the degree of external rotation observed. This is seldom a troublesome feature except in fractures of the upper third of the femur.

LATERAL DISPLACEMENT. This can be discounted up the three-quarters of the width of the bone, if the radiograph in the opposite plane shows sound alignment, and the central axes of the shaft remain parallel. Attempts may be made to control it by the use of lateral pressure, by slings attached to one of the Thomas splint, or by clamps which attach to the side bars of the splint. If the deformity is gross and persistent it is probable that muscle fibres have become interposed, and non-union may result.

POSTERIOR BOWING. It is most important to correct this and maintain it corrected. The femur has normally quite a marked

anterior curvature, which must not be lost if knee movements are to be satisfactory. It is maintained by the use of a *large pad behind* the knee and traction on the leg in the line of the tibia (Figs. 536, 549).

ANGULATION. This is difficult to control in some cases, but is a difficulty particularly met with in fractures of the upper and lower third. If troublesome, and when it cannot be controlled by slings and pads, it is necessary to apply a plaster hip spica. If a satisfactory position is not obtained at first, this is wedged under careful radiological control.

AFTER-TREATMENT. Clinical and radiological union should be established between the twelfth and the sixteenth week, depending on the conditions of the fracture (see p. 139). The question of weight bearing then arises. An attempt to gauge the strength of union should be made. If considered firm, a week's non-weight bearing exercises may be given in bed and the condition of the limb observed. If satisfactory, weight bearing on crutches may be allowed. If unsatisfactory union is present the provision of a calliper may be considered. This enables earlier weight bearing to be permitted at the same time that knee exercises are continued. In other cases where union is sound and in good position at the end of the tenth week, a plaster walking calliper may be made. This has the disadvantage of preventing knee exercises, but if a reasonable degree of knee mobility has been retained this is not a serious matter. It enables the patient to get about earlier and at the end of the fourteenth week the femur is soundly enough united to permit unsupported weight bearing.

Fractures of the upper third of the femoral shaft (Subtrochanteric fractures). These fractures are peculiarly difficult because of the flexion and external rotation which may occur in the upper fragment. If a reasonable position cannot be achieved by flexion of the hip, on a Thomas or Braun's splint, the best method of treatment is open operation and the use of a nail plate.

Where this is not possible the hip may be flexed to a right angle with the knee bent so that the leg is parallel with the floor, and a hip spica applied in this position. With a sling under the flexed knee the patient is easily nursed in this position though it seems a little odd. A Kirschner wire through the tibial tuberosity slung to a Balkan beam may be conveniently used in retaining the limb in position while applying the plaster.

Fractures of the lower third of the femoral shaft (Supracondylar fractures). This fracture is commonly transverse and shows posterior displacement of the lower fragment. This displacement is not due to the pull of the gastrocnemii, as usually described, but to the pull

of the quadriceps, which tends to push the femoral condyles backwards out of the way. It is consequently difficult to reduce and maintain reduction. Reduction can nearly always be accomplished by turning the patient over on his face and suspending the foot from the ceiling. The knee is thus flexed at right angles. Slight traction is applied to the tibial tuberosity. Digital control of the fragments can then usually be obtained and the limb incorporated in plaster, with the knee flexed. Nursing is easy if the limb is allowed to hang over the side of the bed. A disadvantage of this method is the fact that should the quadriceps become adherent to the fracture, it becomes adherent in extension of the knee and it cannot be freed by manipulative methods. This is a more theoretical than practical objection if the prepatellar pouch has not been grossly damaged. In order to avoid a possibility of trouble the knee should be gradually straightened on a Thomas splint as soon as sufficient new bone has occurred around the fracture, somewhere between the fourth and sixth weeks. Active quadriceps exercises are encouraged from the beginning.

Open operation on such cases is technically difficult owing to the difficulties of approach, but may be carried out in exceptional circumstances.

Fractures of the Femur in Children. 1. *Bryant's method.* This is the method of choice for very young children. Strapping or Unna's paste extension is applied from thighs to ankles of both legs, which because of the greater skin area available and the lighter weight of the body is quite efficient. Both legs are then held vertically by weights attached to cords passing over pulleys on a Balkan beam, and are so balanced that the buttocks are just off the bed. The child soon adapts himself to this position and the femur automatically pulls out into a good position. Union is rapid in children and at the end of three to four weeks the child can be allowed to lie in bed and weight bearing allowed at the end of six weeks.

2. *Hamilton Russell method.* This makes use of the resultant of a force acting under the knee in a vertical direction, and one acting along the line of the horizontal leg. If the knee is slightly flexed this resultant corresponds to the line of the femur. Considerable extension may be thus exerted, but there is little control of sagging, or lateral movement. It may be a useful temporary measure, the details of which are apparent from the diagram.

Hamilton Russell's method may be used successfully in adults. By making the direction of pull on the sling behind the knee a little more oblique towards the head the posterior bowing of the leg may be corrected. The system does not provide firm fixation for the femur, but allows early exercises to be carried out.

Compound Fractures of the Femur

These present certain special difficulties, due in part to the difficulties of immobilisation of the femur, and in part to the depth of tissue surrounding the bone, and the strong fascial intermuscular planes. Shock in the early stages may be pronounced, as may blood loss from damage to the deep femoral vessels. Wound excision is practised according to the usual principles, and care is taken to see that there is an adequate opening in the fascia by transverse incision.



Fig. 553. Treatment of fracture of the femur in a child. Bryant's method.

Drainage is made dependent if possible, as pus tends to track up towards the hip joint even if there is an adequate opening anteriorly. Postero-lateral incision in front of the lateral intermuscular septum is safe and satisfactory for drainage.

Immobilisation is by a complete leg plaster attached to a Thomas splint by two cuffs of plaster (Fig. 555), or a "Tobruk" plaster (p. 510). The Thomas splint may then be slung up in the usual manner, giving the patient much more freedom of movement

of the quadriceps, which tends to push the femoral condyles backwards out of the way. It is consequently difficult to reduce and maintain reduction. Reduction can nearly always be accomplished by turning the patient over on his face and suspending the foot from the ceiling. The knee is thus flexed at right angles. Slight traction is applied to the tibial tuberosity. Digital control of the fragments can then usually be obtained and the limb incorporated in plaster, with the knee flexed. Nursing is easy if the limb is allowed to hang over the side of the bed. A disadvantage of this method is the fact that should the quadriceps become adherent to the fracture, it becomes adherent in extension of the knee and it cannot be freed by manipulative methods. This is a more theoretical than practical objection if the prepatellar pouch has not been grossly damaged. In order to avoid a possibility of trouble the knee should be gradually straightened on a Thomas splint as soon as sufficient new bone has occurred around the fracture, somewhere between the fourth and sixth weeks. Active quadriceps exercises are encouraged from the beginning.

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errors in treatment of fractures by continuous traction on a Braun's splint, as summed up by Böhler, may conveniently close the subject.

1. Failure to use local anæsthesia, in period of shock.
2. Failure to use antero-posterior and lateral radiographs.
3. The use of a bed without fracture boards.
4. The use of a badly bandaged Braun's splint.
5. The use of skeletal traction, wires or pins above the knee in fractures of the lower end of the femur. Infection of the blood clot is liable to occur.
6. The use of a traction stirrup in which the pin cannot rotate. The movement of the pin encourages infection.
7. The use of too small traction weights. The weight should commence with one-seventh of the body weight and be increased in the next few hours to 25 to 30 lbs.
8. The use of too great a traction weight. As soon as reduction has occurred the weight is again reduced to one-seventh the body weight.
9. Failure to raise the lower end of the bed to get adequate counter-extension.
10. Failure to use a foot-rest against the lower end of the bed, the patient thus being unable to use his sound leg to raise himself or maintain his position on the splint.
11. Failure to have a bar over the patient's head which he can grip to raise himself.
12. Failure to apply traction to the foot which results in foot drop.
13. Neglect of exercises. General exercises are carried out as soon as possible, and at the end of the third or fourth week exercises of the injured limb are commenced.
14. The use of traction below the knee for too long a period, *i.e.*, over four weeks, which stretches the capsule of the knee.
15. Failure to fix the Braun's splint to the bed so that it slides down to the end of the bed.

Fractures of the Lower End of the Femur

1. Separation of the lower epiphysis.
2. T-shaped fractures into the joint.
3. Separation of the lateral or medial condyle alone.
4. Separation of part of a condyle.
5. Impacted fractures.

Separation of the lower femoral epiphysis. The lesion may occur between the ages of eight and eighteen, and is due to a hyper-extension strain on the joint. The epiphysis is displaced forwards, with resultant pressure of the lower end of the femur into the popliteal space and possible damage to vessels. Partial obstruction of the popliteal artery is inevitable, and may lead to gangrene of the leg if the fracture is not reduced in reasonable time. The fracture line is intra-articular anteriorly and the knee becomes distended with blood. It is rarely compound.

Diagnosis. The end of the femoral shaft may be palpated in the popliteal space. The ridge of the displaced epiphysis may be

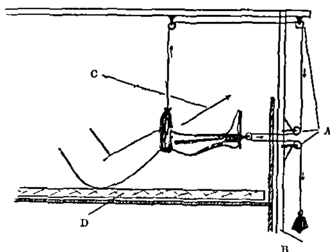


Fig. 554. The principles of the Hamilton Russell method of traction on the femur. A. Pulleys. B. Balkan frame. C. Direction of the resultant pull D. Mattress.

in the bed. For wounds of the upper third of the thigh a plaster hip spica extending to the knee may be useful and the immobilisation of the leg carried out by *putting a Thomas splint over the thigh* plaster and attaching it by plaster cuffs. The leg is then rested in slings in the usual manner and the foot supported by a footpiece at right angles to the leg.



Fig. 555. Complete leg plaster fully split and attached to Thomas splint by a double plaster cuff Skin traction below plaster and separated from the plaster by a layer of cotton wool. One variety of transport plaster.

Summary. It will be seen that the choice of treatment for a fracture of the femur is wide, and depends not only on the points discussed, but to a lesser extent on the type of fracture. Transverse fractures, which can be easily opposed end to end, are more conveniently treated by fixed extension, while oblique and comminuted fractures may respond better to continuous traction. In any form of treatment care and *attention to detail is important, and common*

satisfactory. Perfect reduction is rarely accomplished by manipulative methods. The degree of damage to the condyles, however, may not make it worth while attempting a more perfect reduction. Should the condyle fractured be intact and separated by a single fissure, operative reduction and *screwing of the fragment back into* position is desirable. To do this opening of the knee joint may be unavoidable, but this is not to be feared provided the operative conditions are good.

In spite of considerable damage to the joint surfaces it is often surprising how much flexion returns to the knee. It should be encouraged by early quadriceps exercises and early knee-flexion exercises. It is possible by balancing up the fixation to permit these while traction through the tibial condyle is continued.

Fractures of part of a condyle. These fractures are uncommon, but the posterior half of a condyle may be fractured into the inter-condyloid notch and lie free in the joint. Other smaller fragments may be broken off and lie loose. They should be removed by open operation and the knee treated in a similar manner to that following menisectomy, that is to say, early movements should be encouraged to avoid stiffness at the knee joint.

Small fractures of the condylar surface make up a proportion of the cases of internal derangement of the knee, and it is probable that the incomplete separation of a flake of bone and cartilage is responsible for the condition of arthritis dessicans of the knee.

FURTHER READING

General

Russell, R. Hamilton. "Fracture of the Femur, A Clinical Study," *Brit. J. Surg.*, 1923–24, 11, 491.

Sven Johanssen. "Operative Treatment and Results in Fracture of the Neck of the Femur," *Brit. Med. J.*, 1937, 2, 361.

Santos. "Changes in the Head of the Femur after Complete Intracapsular Fracture of the Neck," *Arch. Surg.*, 1930, 21, 470.

Whitman, R. "The Abduction Treatment of Fracture of the Neck of the Femur," *Surg. Gynæ. and Obstets.*, 1918, 27, 578.

Speed, Kellog. "An Analysis of the Results of Treatment of Fractures of the Femoral Diaphysis in Children under Twelve Years of Age," *Surg. Gynæ. and Obstets.*, 1921, 32, 527.

Charnley, J. "Fractures of the Femoral Shaft, Mechanics of Reduction and Fixation," *Lancet*, 1944, *i.*, 235.

Brunner, W. "Unsere Erfahrungen Mir Det Marknagelung Nach Kuntscher," *Zeit F. Unfallmed U. Berufskrank*, 1947, 40, 103–120.

Macausland, W. R. "Medullary Nailing of Fractures of the Long Bones," *Surg. Gynæ. and Obstets.*, 1947, 84, 85–89.

Boyd, H. B., and George, I. L. "*Complications of Fractures of the Neck* of the Femur," *J. Bone and Joint Surg.*, 1947, 29, 13–18.

Smith Peterson, M. N. "The Treatment of Fractures of the Neck of the Femur by Internal Fixation," *Surg. Gynæ. and Obstets.*, 1937, 64, 287.

palpated above the patella, and the anterior displacement of the whole of the leg in relation to the femoral shaft may be obvious. The adductor tubercle is not altered in level as in supracondylar fractures, as it is attached to the diaphysis. Swelling usually makes this point difficult to determine.

TREATMENT. Reduction is made as soon as possible by traction, combined with antero-posterior pressure on the fragment. Following reduction the knee is fully flexed to settle the epiphysis into position. Retention may be difficult, but is best obtained by flexing the knee to 90° and fixing it in a plaster spica. This is applied with the patient on his face and the foot held with the sole uppermost. It is maintained for four weeks and then the limb gradually straightened. Weight bearing is allowed at the end of eight weeks. There is no interference with growth if the separation is correctly reduced.

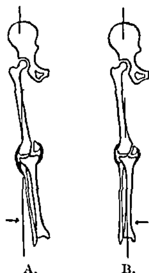


FIG 556A. Fracture of the medial condyle of the femur. Upward displacement associated with adduction of the leg.
FIG. 556B. The correction of the displacement shown in the previous figure by abduction of the leg at the knee.

Fractures of a single condyle. These are due to forced abduction and adduction movements of the knee, rarely to direct violence. Fracture of the medial condyle is brought about by adduction. Less commonly this produces a ligament traction fracture at the insertion of the external collateral ligament of the knee into the condyle. A similar lesion can occur with the internal collateral ligament in forced abduction For ligament traction fractures a resting plaster from thigh to ankle, in which the patient can walk (Fig. 112), is required for three to four weeks.

In the more extensive injury the whole condyle is separated, the fracture line running through the intercondyloid notch. The condyle may be pushed up to some extent, less commonly rotated, or, if the foot is displaced, it may be pulled down. The knee is distended with blood which should be aspirated before reduction is attempted.

REDUCTION. The collateral ligaments remain attached to the condyles, and so forced abduction or adduction of the leg may be made to pull the condyle down into position. Compression is rarely required. For correct observation of these fractures the Braun's splint is unsuitable as the flexed knee destroys to some extent the value of the antero-posterior X-ray control, and also masks abduction or adduction of the leg. A Thomas splint will be found more

satisfactory. Perfect reduction is rarely accomplished by manipulative methods. The degree of damage to the condyles, however, may not make it worth while attempting a more perfect reduction. Should the condyle fractured be intact and separated by a single fissure, operative reduction and screwing of the fragment back into position is desirable. To do this opening of the knee joint may be unavoidable, but this is not to be feared provided the operative conditions are good.

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Sven Johanssen. "Operative Treatment and Results in Fracture of the Neck of the Femur," *Brit. Med. J.*, 1937, 2, 361.

Santos. "Changes in the Head of the Femur after Complete Intracapsular Fracture of the Neck," *Arch. Surg.*, 1930, 21, 470.

Whitman, R. "The Abduction Treatment of Fracture of the Neck of the Femur," *Surg. Gynæ. and Obstets.*, 1918, 27, 578.

Speed, Kellog. "An Analysis of the Results of Treatment of Fractures of the Femoral Diaphysis in Children under Twelve Years of Age," *Surg. Gynæ. and Obstets.*, 1921, 32, 527.

Charnley, J. "Fractures of the Femoral Shaft, Mechanics of Reduction and Fixation," *Lancet*, 1944, i., 235.

Brunner, W. "Unsere Erfahrungen Mir Det Marknagelung Nach Kuntscher," *Zeit F. Unfallmed U. Berufskrank*, 1947, 40, 103–120.

Macausland, W. R. "Medullary Nailing of Fractures of the Long Bones," *Surg. Gynæ. and Obstets.*, 1947, 84, 85–89.

Boyd, H. B., and George, I. L. "Complications of Fractures of the Neck of the Femur," *J. Bone and Joint Surg.*, 1947, 29, 13–18.

Smith Peterson, M. N. "The Treatment of Fractures of the Neck of the Femur by Internal Fixation," *Surg. Gynæ. and Obstets.*, 1937, 64, 287.

FARKAS, A. *et al.* "An Anatomical Study of the Mechanics, Pathology and Healing of Fracture of the Femoral Neck," *J. Bone and Joint Surg.*, 1948, 30A, 53.
Per LINTON. "Types of Displacement in Fractures of the Femoral Neck," *J. Bone and Joint Surg.*, 1949, 31B, 184.
CREGAN, J. F. "The Use of the Acrylic Prosthesis in High Fracture of the Femoral Neck," *J. Bone and Joint Surg.*, 1954, 36B, 411.
EYRE-BROOK, A. L., and PRIDIE, K. H. "Intracapsular Fractures of the Neck of the Femur. Final Results in 75 Consecutive Cases." *Brit. J. Surg.*, 1941, 29, 115.

Pertrochanteric Fractures

ANDERSON, ROGER. "New Method for Treating Fractures Utilising the Well-leg for Counter Traction," *Surg. Gynæ. and Obstets.*, 1932, 54, 207.
EVANS, E. M. "Trochanteric Fractures," *J. Bone and Joint Surg.*, 1951, 33B, 192.
SCOTT, J. C. "Treatment of Trochanteric Fractures," *J. Bone and Joint Surg.*, 1951, 33B, 508.

Reconstruction Operations

McMURRAY, T. P. "Ununited Fracture of the Neck of the Femur," *J. Bone and Joint Surg.*, 1936, 18, 319.
COMPERE and LEE. "The Restoration of Physiological and Anatomical Function in Old Ununited Intracapsular Fractures of the Neck of the Femur," *J. Bone and Joint Surg.*, 1940, 22, 261.

Slipped Epiphysis

McCAUSLAND, A. R. "Separation of the Capital Femoral Epiphysis," *J. Bone and Joint Surg.*, 1935, 17, 353.
WARDLE, E. N. [illegible] of the Femur [illegible]
MILCH. "Epiph[illegible] *Surg.*, 1937, 19, 97.
POMERANZ and SLOANE. "Slipping of the Proximal Femoral Epiphysis," *Arch. Surg.*, 1935, 30, 607.
WILSON. "The Treatment of Slipping of the Upper Femoral Epiphysis with Minimal Displacement," *J. Bone and Joint Surg.*, 1938, 20, 379. (Recommending Smith Petersen Nail.)
MARTIN, P. H. "Slipped Epiphysis in the Adolescent Hip," *J. Bone and Joint Surg.*, 1948, 30A, 9.
HOWARTH, M. B. "Slipping of the Upper Femoral Epiphysis," *J. Bone and Joint Surg.*, 1949, 31A, 734.

Femoral Shaft

WINANT, E. M. "Use of Skeletal Traction in Fractures of the Femur," *J. Bone and Joint Surg.*, 1949, 31A, 87.
DELORME, WEST and SHRIBER. "Influence of Progressive-resistance Exercises on Knee Function following Femoral Fractures," *J. Bone and Joint Surg.*, 1950, 32A, 910.
CHARNLEY, J. "Knee Movement following Fractures of the Femoral Shaft," *J. Bone and Joint Surg.*, 1947, 29, 679.
CHARNLEY, J. "Fractures of the Femoral Shaft," *Lancet*, 1944, i., 235.

CHAPTER XXVIII

FRACTURES OF THE PATELLA

Surgical anatomy. The patella is to be regarded as a sesamoid bone in the tendon of the quadriceps. In spite of the statement by Brooke that the patella is either absent or vestigial in the faster-moving quadrupeds, and is, therefore, "phylogenetically inherited and its presence is not determined by function," we believe that it serves three useful purposes. It protects the articular surface of the femur in flexion of the knee, it takes some of the frictional strain on the ligamentum patellæ, and by holding the ligament away from the anterior surface of the femur increases the efficiency of the quadriceps in the last stages of extension.

Development. The patella is ossified from one centre as a rule, but occasionally there may be separate centres for the upper and outer portions of the bone. These are usually bilateral, and are not to be confused with fracture (Fig. 564).

FRACTURES of the patella are a particularly good example of the fact that the fracture is often a guide to the soft tissue injury, which is the most important injury in the majority of fractures and of paramount importance in this case. The principal factor with which we are concerned is the quadriceps expansion, and whether it is intact or not. The patella lies within this, being a sesamoid. The quadriceps insertion and its expansion which form the extensor mechanism of the knee, may be ruptured at various levels. The attachment of the muscle may be pulled from the upper margin of the bone, and this may be indicated later by the formation of new bone in this area. The transverse fracture near the centre of the bone due to muscular violence is accompanied by ruptures of the fibrous expansion of the muscle on either side. Fractures of the lower pole of the bone at the attachment of the ligamentum patellæ are also sometimes accompanied by a similar rupture, though they often occur without displacement. Finally fractures of the tibia around the insertion of the muscle complete the series of injuries to which the expansion is liable.

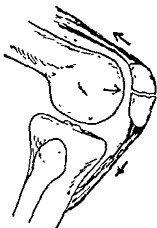


FIG. 557. Fracture of the patella by muscular violence. The patella is broken over the lower surface of the femur.

Fractures unassociated with damage to the extensor mechanism are due to direct violence, and consist of single chips from the margins of the bone, multiple fissures, or gross comminution of the bone. It must not be forgotten that damage to the femoral surface

of the bone may occur without any changes being visible in the radiograph, and that this may occur from the patella being forced violently across the outer femoral condyle, such as occurs in dislocation of the patella.

Varieties of Patella Fracture

Variety	
1. Transverse fracture of the body 2. Transverse fracture of the lower pole.	With separation, accompanied by rupture of the quadriceps expansion.
3. Transverse fracture of the body 4. Transverse fracture of the lower pole.	Without separation of the fragments, expansion intact, due to direct violence, or leverage.
5. Comminuted fractures . . . 6. Chip fractures . . . . 7. Vertical fracture	Due to direct violence.

I. Transverse fracture of the body of the patella. This fracture is the most serious, due to the widespread rupture of the fibrous expansion of the muscle on either side of the patella, and the fact that the fracture line is near enough to the centre of the bone to be a constant irritation to the femur in flexion of the knee, however well it is reduced. The later development of patello-femoral arthritis is therefore to be expected.

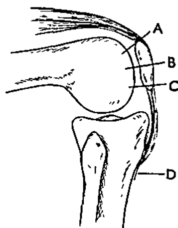


Fig. 558 Rupture of the extensor mechanism of the knee
A. Attachment to upper border of patella.
B. Transverse fracture of the patella
C. Rupture of the attachment of the patella tendon together with separation of small non-articular fragment.
D. Rupture at attachment of the tibial tubercle, accompanied by fracture of the tibial tubercle.

The fracture is due to sudden strain on the quadriceps, usually with the knee *in the semiflexed position.* The patella is caught across the anterior surface of the femur, is snapped, and continuation of the flexion of the knee together with muscular contraction tears the expansions of the muscle and the two fragments of the bone widely apart.

Signs and Symptoms. These are usually dramatic and unmistakable. There is a loss of control of the knee and an inability to raise the leg with the knee straight. There is a rapid *effusion of* blood into the knee joint which is distended, and usually an effusion into the prepatella bursa which is also distended and sits on the swollen knee like a small hill

on a larger one. Bruising and hæmorrhage are usually visible in the subcutaneous tissues, and the two separate fragments may be



Fig. 559. Fracture of the patella with displacement.

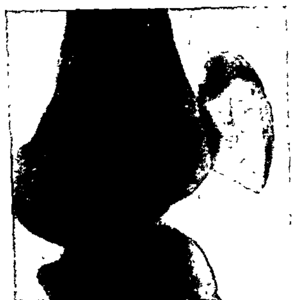


Fig 560. The same case as in the previous figure after suturing the expansions and the bone.

felt to move independently of each other while the gap between them is unmistakable.

Treatment Operative repair of the torn expansion of the quadriceps is essential, at the same time the likelihood of the development of sub-patella arthritis must be borne in mind, particularly

of the bone may occur without any changes being visible in the radiograph, and that this may occur from the patella being forced violently across the outer femoral condyle, such as occurs in dislocation of the patella.

Varieties of Patella Fracture

1. Transverse fracture of the body 2. Transverse fracture of the lower pole.	With separation, accompanied by rupture of the quadriceps expansion.
3. Transverse fracture of the body 4. Transverse fracture of the lower pole.	Without separation of the *fragments*, expansion intact, due to direct violence, or leverage.
5. Comminuted fractures . . . 6. Chip fractures . . . . 7. Vertical fracture . . .	Due to direct violence.

1. TRANSVERSE FRACTURE OF THE BODY OF THE PATELLA. This fracture is the most serious, due to the widespread rupture of the fibrous expansion of the muscle on either side of the patella, *and the fact that the fracture* line is near enough to the centre of the bone to be a constant irritation to the femur in flexion of the knee, however well it is reduced. The later development of *patello-femoral arthritis is therefore* to be expected.

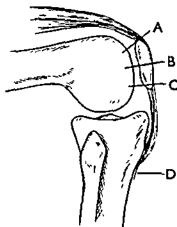


FIG 558. Rupture of the extensor mechanism of the knee.
A. Attachment to upper border of patella
B. Transverse fracture of the patella.
C. Rupture of the attachment of the patella tendon together with separation of small non-articular fragment.
D. Rupture at attachment of the tibial tubercle, accompanied by fracture of the tibial tubercle.

The fracture is due to sudden strain on the quadriceps, usually with the knee in the semiflexed position. The patella is caught across the anterior surface of the femur, is snapped, and continuation of the flexion of the knee together with muscular contraction tears the expansions of the muscle and the two fragments of the bone widely apart.

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on a larger one. Bruising and hæmorrhage are usually visible in the subcutaneous tissues, and the two separate fragments may be



Fig. 559. Fracture of the patella with displacement.

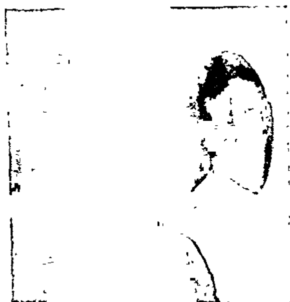


Fig 560 The same case as in the previous figure after suturing the expansions and the bone.

felt to move independently of each other while the gap between them is unmistakable.

Treatment. Operative repair of the torn expansion of the quadriceps is essential, at the same time the likelihood of the development of sub-patella arthritis must be borne in mind, particularly

in the old. Preliminary treatment consists of the aspiration of the knee, which is then firmly bandaged over cotton wool and placed on a Cramer wire back splint. After a few days for the bruising to subside, or immediately, repair of the quadriceps is undertaken. The decision as to the fate of the patella depends on (1) The age of the patient; (2) The presence of osteoarthritis; (3) The size of the fragments. Thus in an elderly patient with osteoarthritis the patella is best excised. In old people in whom patello-femoral arthritis is likely it is also excised. In young people who have not ceased growing it may be completely repaired, while in young adults it may be best, especially if the fragments are unequal in size, to excise the

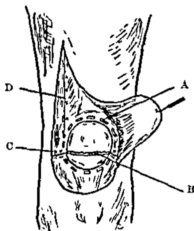


Fig. 561. The operation for fascial repair. A. Fascial strip woven around the patella. B. Fissure fracture of the patella. C. Suturing in the torn quadriceps expansion. D. Suture of the incision in the fascia lata from which the strip was obtained.

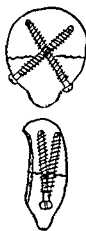


Fig. 562. The position of the screws in uniting a transverse fracture of the patella.

smaller one and attach the patella tendon to the larger one. This method has the advantage of retaining part of the patella without the subsequent risk of arthritis

Repair of the patella. Numerous methods of operation have been devised since Lister first placed a wire suture in the bone. The object is to produce a smooth under-surface to the bone and so avoid the development of a sub-patellar arthritis later. It is therefore only suitable for transverse fractures with two large fragments which interlock perfectly, or in the young, in which growth can be relied on to even up any slight irregularity in the surface. If there is one small fragment it is better excised and the ligament attached to the margin of the fracture If there is comminution or irregularity the patella is often best excised.

Earlier methods employed consisted of a fascia lata suture as shown in Fig. 561, or wiring as shown in Fig. 563. These may be satisfactory but are unreliable. Much greater stability is obtained by the use of crossed screws (Fig. 562). These not only prevent displacement in the antero-posterior plane, which would leave a ridge on the under-surface, but by opposing separation permit early exercises safely. Holding the two halves perfectly reduced by bone spikes, the patella is drilled and screwed. The rents in the retinaculum often permit inspection of the under-surface, but perfect reduction of the surface means perfect reduction of the under-surface. The screws need not be removed subsequently. As in all patella operations a satisfactory result depends on the after-treatment (see below), and this in turn depends on complete confidence in the suture line.

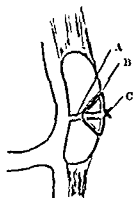


Fig. 563. Another method of patella suture. A. Transverse fracture of the patella. B. Oblique drill hole. C. Knotted catgut tied through drill holes. This method obviates any suture lying on the articular surface.

Excision of the patella. Through a curved vertical or transverse incision (curved with base down to avoid the prepatella bursa being involved in the scar) the patella fragments are freed as close to the bone as possible. The two portions of the patella tendon are then united by a figure-of-eight of plaited stainless steel wire, getting a firm grip on each side of the patella gap. With two sharp hooks the quadricepetal portion is drawn down and the suture tied. The rents in the lateral expansions of the quadriceps are then repaired with strong catgut. Perfect confidence can then be placed in the suture line, so that early exercises may be given. The plaited wire may break with use later on, but by that time union has occurred. The occurrence of a hæmatoma in the prepatella bursa should be avoided as tension may jeopardise the blood supply to the skin over it. Drainage for twenty-four hours does no harm, if in doubt about hæmostasis.

After-treatment (*all cases*). A Robert Jones' pressure dressing is applied. This consists of a layer of wool and then a calico bandage applied over another calico bandage and layer of wool. This has the advantage of loosening gradually as muscular control of the knee returns. Quadriceps contractions and gentle faradism are begun at once and the patient encouraged to flex the knee as far as possible in the bandage. At the end of three weeks this is removed and active flexion exercises commenced. Weight bearing is permitted about the end of a month. Flexion to a right angle should be possible

between this time and the eighth week. Full recovery of flexion is slow, particularly in the aged.

Prognosis. This is uniformly good in all cases as far as the immediate results are concerned. In older patients in whom the patella has not been excised patello-femoral arthritis will develop. In cases in which the halves of the patella are not firmly approximated, union by fibrous tissue is likely to occur. This is compatible with a good functional result.

2. TRANSVERSE FRACTURE OF THE LOWER POLE WITH SEPARATION. The small fractured fragment has the main bulk of the patella ligament attached to it, but in the majority of cases the fracture line does not cross the articular area of the bone, lying just at the lower margin of the articular surface. If this is so no danger of subsequent sub-patella arthritis need be felt if the fragment is fixed back in position If the articular area is involved, the smaller lower fragment may be excised The ruptured lateral expansions of the quadriceps are repaired with care as in transverse fractures of the body.

3. TRANSVERSE FRACTURES OF THE BODY AND 4. TRANSVERSE FRACTURES OF THE LOWER POLE WITHOUT SEPARATION. These cases may be due to direct violence, or more commonly to the patella being caught across the condyles of the femur and snapped without the displacement of the knee proceeding any further. The extensor mechanism is intact and the fragments not displaced. Aspiration of the knee is followed by early active use of the knee. This is the type of case in which the irregularities of blood clot or fibrinous bodies in the prepatella bursa may cause diagnostic confusion. The absence of bruising in these latter cases or of effusion into the knee should aid in the differential diagnosis, while it should be remembered that chronic prepatella bursitis is often bilateral.

5. COMMINUTED FRACTURES. These are due to severe direct violence and the anterior surface of the femur suffers as well. The collision of a motor cyclist with a vehicle, or the knee being thrown against a dashboard, are common methods of producing the fracture, and it may be associated with fractures of the femur. Owing to the grave risk of subsequent sub-patella arthritis the patella should be excised in all cases. Preliminary aspiration of the joint, a few days' rest and adequate preparation are desirable, but the frequency of abrasions or of compound wounds often forces emergency operation. The principles of treatment of open injuries are similar to those elsewhere. Should it be considered that there is serious risk of infection of the knee joint, great care should be taken to sew up the synovial membrane. Approximation of the fibrous expansion of the quadriceps can be left to a later date, as the large body of buried catgut may cause serious trouble if sepsis occurs. Drainage is wise for the

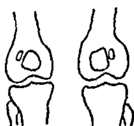


Fig. 564. Congenital abnormalities of the patella. The patella ossifies from two centres which fail to fuse. This is often mistaken for marginal fracture of the patella.

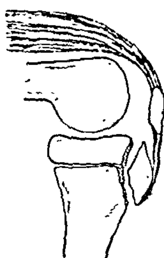


Fig. 565. Fracture of the epiphysis for the tibial tuberosity when this develops as a downgrowth from that for the tibial plateau.



Fig. 565a. Separation of the epiphysis for the tibial tubercle.



Fig. 566. Old Osgood Schlatters' disease with persistent fragmentation of the tibial tubercle, susceptible to strain.

first twenty-four hours in all cases, as pressure of blood in the prepatella bursa may produce gangrene of skin over the bursa, but if desired the wound may be left open for secondary suture.

6. Chip fractures. These occur due to direct violence and may



Fig. 567. Avulsion of the tibial tubercle.



Fig. 567a. Reduction of the fracture and fixation with single screw.

be compound. If the chip is intra-articular, or involves the articular surface in an irregularity because of its displacement, it should be removed. If in good position they are left. Care is to be taken to avoid confusion with the congenital abnormality seen in Fig. 564. This is usually bilateral and involves the upper and outer angle of the bone. Confusion arises because the shadow of the fracture line cannot be thrown clear of the femoral shadow, but when it can it has the characteristics of a congenital abnormality.

Fractures of the tibial tubercle. It seems appropriate here to add a note on fractures of the tibial tubercle. This arises as a tongue-shaped extension of the tibial epiphysis and not infrequently has a separate centre of ossification. This fuses with the shaft at the age of eighteen. The epiphysis is liable to osteochrondritis commonly called Osgood Schlatter's disease. This shows the characteristic changes of density and fragmentation, and may result in a failure of the tubercle to unite with the shaft properly, a separate small bony fragment remaining (Fig. 565). This condition is often bilateral and characterised by excessive prominence of the tubercles, which may be tender to touch

If they are submitted to long-continued strain, such as route marching, complaint of pain will be made. The condition may then be diagnosed as a fracture. Careful inspection will show it to have all the characteristics of well-organised bone (p. 29).

It is in youth when the epiphyseal line presents a weak area through which separation may occur that injuries to the tubercle are common. If a separate centre for the tubercle is present it may be avulsed, or if the whole epiphysis is ossified as one the tongue-like depression over the upper end of the tibia may be avulsed. In such cases operative repair is necessary. The fragments can usually be held in position by suturing the surrounding fibrous tissues, or by a single drill hole in the fragment, and a strong wire suture through bone. Screwing may be carried out (Fig. 567), but the screw should be removed in the young as soon as the fractured fragment is firmly attached.

FURTHER READING

BROOKE. "The Treatment of Fractured Patella by Excision. A Study of Morphology and Function," *Brit. J. Surg.*, 1937, 24, 733. (Advocates complete removal in all cases.)

BLODGETT and FAIRCHILD. "Fractures of the Patella," *J. A. M. A.*, 1936, 106, 2121. (This comprehensive article advocates more conservative treatment, though not denying the value of complete excision in certain cases. Full references.)

ADAMS and LEONARD. "A Developmental Anomaly of the Patella, frequently Diagnosed as Fracture." *Surg. Gynæ. and Obstets.*, 1925, 41, 601.



FIG. 567. Avulsion of the tibial tubercle.



FIG. 567A. Reduction of the fracture and fixation with single screw.

CHAPTER XXIX

FRACTURES OF THE TIBIA

Surgical anatomy and development. A primary centre for the shaft develops about the seventh to eighth week. Secondary centres appear as follow :—

Tibia

Upper end. Just after birth. Unites eighteen to twenty.
Lower end. In second year. *Unites after puberty.*

The tibia is a characteristic long bone, the upper end being an expanded cancellous tissue plateau for the support of the femoral condyles. The triangular shape of the shaft on section predisposes to sharp corners at a fracture site, while its subcutaneous surface makes them readily compound. The upper epiphysis has a tongue-like prolongation anteriorly which carries the tibial tubercle, and the articular area for the fibula is localised to it. Owing to the fact that most of the ligaments of the region are attached to the bone below the epiphysis it is very rarely separated. If a secondary centre is present for the tongue of the epiphysis to which the patella ligament is attached, this may be fractured, and rarely the tongue may be avulsed.

The anterior cruciate ligament runs from the anterior portion of the tibial spine to the medial intercondyloid surface of the lateral femoral condyle. It *is tight in extension, and if ruptured allows excessive forward mobility of the* tibia. The posterior cruciate ligament runs from the posterior aspect of the tibial spine to the anterior medial aspect of the inner femoral condyle, and is tight in flexion. Rupture allows excessive backward mobility of this tibia on the femur. Both these ligaments should be tested for with the knee flexed to a right angle, the foot on the table, and the thigh muscles completely relaxed.

The lower epiphysis of the tibia is much more susceptible to injury than the upper, and is not infrequently displaced. The fibula epiphysis may be *displaced at the same time, or the displacement may be accompanied by the* fracture of the fibula.

Fractures of the Upper End of the Tibia

1. Fractures of the tibial crest.
2. Fractures of the tibial condyles (tuberosities).
3 Fractures below the condyles.
4. Fractures of the tibial tubercle (p. 529).

Fractures of the tibial crest. 1. Fractures of the anterior tubercle. This lies *anterior to* the spine, and is the site of attachment of the anterior cruciate ligament. The fracture is an avulsion, or ligament traction fracture, due to a blow on the *anterior aspect* of the femoral condyles with the knee flexed, which drives the femur backward on the fixed tibia. In a similar manner the posterior cruciate ligament may be damaged by blows driving the tibia backward with the knee flexed.

2. Fracture of the tibial spine. This is due to a blow from

LAPIDUS. "Longitudinal Fractures of the Patella," *J. Bone and Joint Surg.*, 1932, **14**, 351.
TODD and MCCALLY. "Defects of the Patella Border," *Ann. Surg.*, 1921, **74**, 775.
COLEMAN, H. M. "Recurrent Osteochondral Fracture of the Patella," *J. Bone and Joint Surg.*, 1948, **30B**, 153–157.
SCOTT, J. C. "Fractures of the Patella," *J. Bone and Joint Surg.*, 1949, **31B**, 76.

anterior end of the cruciate ligament with a bone peg or suture, passed by drilling the tibial condyle from below. The results of cases treated without fixation seem equally satisfactory. The post-operative treatment is the same as for fractures of the patella requiring operation.

Fractures of the tibial condyles

1. Fractures of the tibial plateau on the medial or lateral side. (*a*) Involving the outer edge of the plateau only (Fig. 569).

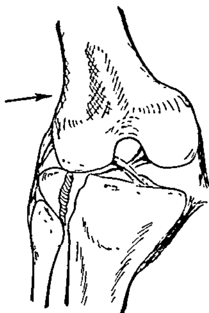


Fig. 569. Fracture of the outer margin of the tibial plateau leaving most of the articular surface intact. (Compare Fig. 575.) This may occur with (as shown) or without rupture of the medial collateral ligament—for mechanism, compare Fig. 571.

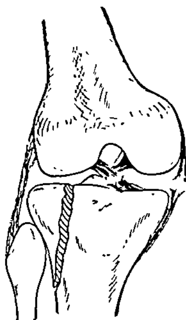


Fig. 570. Fissure fracture of the outer half of the tibial plateau with little displacement. The absence of this is due to the rupture of the medial collateral and anterior cruciate ligament.

(*b*) Involving the whole medial or lateral plateau surface, which is angulated but not depressed or fragmented. This fracture may be accompanied by rupture of a collateral ligament.

(*c*) Depressed fissure fractures or comminuted fractures of the plateau, which may take several forms (Figs. 580, 581), may be accompanied by collateral ligament rupture, and because of the severe intra-articular damage have a bad prognosis.

2. Comminuted fractures of both condyles (Fig. 582). The importance of injuries to the tibial articular surface is as great as that of injury to the femoral condyles. They both, if incorrectly

the inner surface of a condyle, as one or other side of the intercondyloid notch is moved across against the spine. To allow this degree of movement either one or both collateral ligaments of the knee must be severely sprained or ruptured.

3. To complete the summary of the condition, lesions associated with comminuted fractures of the tibial condyles must be mentioned.

DIAGNOSIS. There are three characteristics of the lesion, a hæmarthrosis, with some limitation of the knee movements, a bony block to full extension of the knee, not always present, and some associated relaxation of the ligaments of the knee. If the anterior cruciate is torn, abnormally free antero-posterior movements of the extended knee are possible. If a collateral ligament of the knee is ruptured abnormal abduction or adduction movements of the knee are allowed. The diagnosis can only be made by radiography, as a simple hæmarthrosis, loose bodies, or other fracture into the knee may cause confusion.

TREATMENT. In the majority of cases, full extension of the knee after aspiration of the joint causes the fragment of bone to slip back into position and maintains it there. Some manipulation may be required to get the knee into full extension, some rotatory movements of the foot with the knee semiflexed usually causing it to slip back. The knee is then immobilised on a Cramer wire back splint with a pressure bandage to the knee. At the end of five to ten days a plaster cast as for fractures of the patella is applied, and walking permitted. This is removed at the end of six weeks and gentle exercises commenced.



FIG. 568. Fracture of the spine of the tibia. Elevation of the attachment of the anterior cruciate, due to the femur being forced back on the fixed tibia. Treated by forcing the knee into full extension.

Occasionally the fragment fails to slip back into position, or cases may be seen which are not diagnosed till the fragment has united in a position limiting extension. In such cases the fragment must be replaced or removed by open operation, and the knee fully extended. In these cases it is occasionally found that a torn or displaced meniscus is preventing reduction or full extension of the joint. It is debatable whether it is of value to fix the

or T-shaped fractures into the joint. If there is any angulation the depression is confined to one condyle. Compression fractures with a firmly extended knee may cause compression of the cancellous bone below the articular surface without distortion of the articular surface.

2. ANGULATION. In angulation injuries there is a balance of damage shared between the collateral ligaments of the joint on the

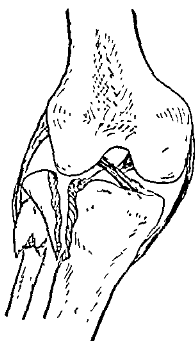


FIG. 573. Fissure fracture of the tibial plateau with fracture of the neck and displacement. A characteristic lesion when the intact ligaments provide sufficient leverage.

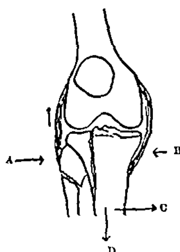


FIG. 574. Diagram indicating the necessary forces to reduce the fracture shown in the previous figure. AB. Direction of compression. C. Forced adduction of the leg producing tension in the fibula collateral ligament. D. Traction on the leg further increasing this tension and separating the joint surfaces.

one side and the condyle of the tibia of the opposite side. If the ligament tears, the knee joint opens on that side more easily, and there is less energy expended in driving the sharp edge of the femoral condyle into the upper surface of the tibia. If the ligament holds, the force is expended in depressing, comminuting, or splitting off the condyle of the opposite side.

Blows on the outer aspect of the leg are much more common than on the inner aspect, and are characteristically produced by the bumper bars of a car. Abduction fractures of the knee are thus

replaced, have a deleterious effect on the joint function, altering the line of stress through the joint, and distorting movement so that a large number of cases end with a severe traumatic arthritis. To avoid this accurate reduction is a *sine qua non.*

Further, owing to the ligament damage, adequate rest (ten weeks) must be given for these to heal and during this time it is important to maintain quadriceps tone, by all means at your disposal. If the

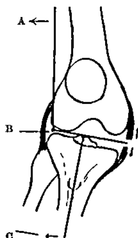


Fig. 571. The mechanism of fractures in the knee region from indirect violence. A. Direction of force offered by the resistance of the femur. B. The site of the fulcrum. C Direction of leverage exerted by forced abduction of the tibia. The arrows show the strain on the medial collateral ligament. The conditions are reversed in adduction fractures.

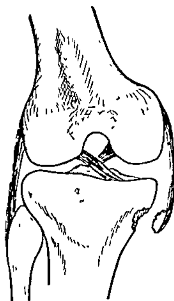


Fig. 572. Ligament strain fracture of medial condyle of the tibia, from abduction violence to the leg The opposite lesion from adduction strain is shown in Fig. 752, while rupture of the ligament alone is shown in Fig. 671

knee is unstable owing to the ligamentous and bony damage, only the power of the muscles will maintain it in satisfactory working order. Any irregularity of the tibial plateau surface is still another contributory factor to the onset of traumatic arthritis and demands that, as far as possible, the tibial plateau be restored to its old level and regularity.

The Mechanism of Fractures of the Tibial Plateau

Compression. This may occur in falls from a height with the knee extended. This produces depressed fractures of both condyles

tibial attachment. Occasionally a small flake of bone is avulsed from the tibial condyle. The flake is seldom much displaced and is restored by manipulation and full adduction of the knee, after aspiration of the joint. The knee should be immobilised in plaster for six weeks, quadriceps tone being maintained. The prognosis, when there is an accompanying fracture, is better than when the ligament itself is torn and the repair more rapid. Complete ligament ruptures without fracture require ten to twelve weeks' rest.

Sprain fractures of the styloid process of the fibula. This lesion corresponds to the fracture described above and occurs during adduction strains on the knee. The displacement is variable, one case being recorded in which the fragment was caught in the knee joint in an analogous manner to that of the medial epicondyle in the elbow joint. Satisfactory position is usually achieved by full extension and the leg should be fixed in plaster for six to eight weeks.

Avulsion by the ilio-tibial band. Occasionally a small flake of bone is avulsed from the antero-lateral surface of the tibia below the joint surface. It may accompany rupture of the fibular collateral ligament. Its origin may be difficult to explain if the insertion of the band into this area has been forgotten.

Avulsion by the coronary ligaments. In gross injuries of the knee due to tearing of collateral ligaments small flakes of bone may be avulsed, by these ligaments which are part of the anchoring mechanism of the menisci.

General observations. Two main principles must be followed, the first is to achieve as complete an anatomical restoration as is possible within the limitations set out below, and the second to concentrate on early function of the knee, and to adopt methods which favour this. Though the tibial plateau may be gravely damaged, remarkably good function may be restored to the knee by this regime, and how long such a knee will give useful service before a crippling traumatic arthritis demands arthrodesis.

In the attempt to restore anatomical position it is tempting to use combinations of plates, screws and bolts. These must be used with care as operative interference is never easy, and the exposure is likely to deprive fragments of bone of



FIG. 577. Fracture of both bones of the leg at the same level.

much more common than adduction fractures. With the abduction lesion the upper end of the fibula is sometimes damaged by direct violence, though more frequently it is fractured by depression of the lateral femoral condyle. In adduction fractures the fibula is damaged by ligament strain.

In all cases steps should be taken to prove or disprove rupture of a collateral ligament by examination under anæsthesia and *control radiography. In some cases* the cruciate ligaments may be ruptured as well. It is probable that the type of fracture is dependent on whether the blow on the outer side of the leg is struck above or below the knee. If the blow is just below the knee the tibia moves in under the femoral condyle and the plateau is depressed as a whole (Fig. 575). If the blow is struck on the femur, the femur moves inwards and the sharp outer edge of the femoral condyle splits or depresses the tibial plateau.

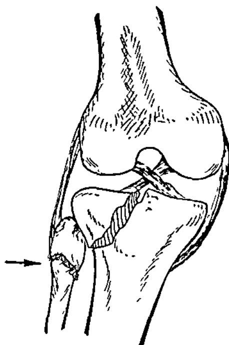


FIG. 575. "Bumper fracture." The mechanism and fracture varies according to whether the bumper strikes above or below the knee. If below, and the ligaments remain intact, a depressed fracture of the outer side of the tibial plateau and of the fibula at the neck occurs—if the force strikes above the knee, as in Fig. 569, depressed fractures of the plateau without fracture of the fibula tend to occur.



FIG. 576. Depressed fracture of the outer half of the tibial articular surface for the lateral femoral condyle. Restored to normal position by forced adduction and plaster retention.

3. AVULSION. This may affect the attachments of the collateral ligaments, or the attachment of the fascia lata to the lateral condyle of the tibia.

Sprain fractures of the tibial attachment of the medial collateral ligament. When the medial collateral ligament ruptures it may give at the femoral attachment, stretch opposite the joint line, or at the

weight-bearing be considered necessary, a knee fixation plaster may be applied and active exercises in this commenced. This is worn for a month to six weeks. A satisfactory functional recovery is to be anticipated with either method, the disability persisting longer if plaster is used on account of the stiffness of the joint.

Fractures involving one-half of the tibial plateau. In these fractures the pressure imparted by the femoral condyle is applied evenly over the surface of one tibial condyle. This is more likely to occur if the tibial surface is displaced under the femoral condyle at the moment of pressure, as occurs *when it is first driven sidewards by force applied below the knee* (Fig. 575). The ligaments, if remaining intact, contribute to this by preventing displacement and preventing further tilting of the femoral condyle. After depression has occurred they may be ruptured, permitting continued displacement of the bones on each other. Fracture of the fibula is inevitably associated with this lesion if it affects the outer plateau, though in some cases this may be produced by the actual violence. It is then more likely to be accompanied by paralysis of the peroneal nerve.

Treatment. The ligaments fixed to the condyle and the fibula enable it to be elevated by forced abduction or adduction (Fig. 574). The fracture line usually involves the intercondyloid region and there is less risk of early traumatic arthritis than in cases in which comminution of the plateau is present. Reduction may be aided by the use of a lateral clamp of the Böhler type, or the Phelps-Gocht clamp. More convenient than this is the use of an Esmarch bandage, by means of which great compressive force may be applied. Reduction, if not perfect, usually produces a good functional result. The meniscus may be damaged and require removal later, but this is less common than in the succeeding group of cases.

After-treatment will depend on the assessment of the stability of the knee. If thought stable it may be treated by a Robert Jones bandage and static quadriceps exercises, working slowly up to flexion of the knee. Most commonly this is risky, and retention is best aided by traction through the tibial tuberosity, which does not prevent the early exercise of the knee. This is maintained for three to four weeks, and the knee subsequently supported by a Robert Jones bandage, and given non-weight bearing exercises. Weight bearing may commence about the tenth week. Occasionally when there has been a good recovery of flexion of the knee, weight bearing may be permitted in a plaster at an earlier date. This should not produce any increased stiffness of the knee.

Alternatively in undisplaced fractures and in fractures in children, the limb may be put in plaster and active quadriceps exercises begun immediately after aspiration and reduction of the fracture. Weight bearing is not permitted for some weeks (four to six), depending on the extent of the depressed area, and then only in a well-fitted plaster. During this period the knee is actively exercised. At the end of ten to twelve weeks the plaster is removed and active flexion exercises begun. It is rare that this group of cases needs operative reduction, but occasionally it is necessary to do this. Through an antero-lateral or antero-medial incision the condyle is replaced, any loose body removed from the joint, and the cartilage excised if affected. The after-treatment is similar to that in cases non-operatively treated.

Depressed and comminuted fractures of a tibial condyle. When the force employed is greater, or strikes the femur instead of the tibia, and particularly if ligamentous rupture has occurred, the sharp edge of the femoral condyle (in particular the lateral condyle) may split off the outer

their blood supply and so add to the damage. Depressed fragments of the tibial plateau come into this category, and they can seldom be restored to their normal level and retained there, by packing and fixation without being rendered avascular. The prolapse of damaged menisci, and the fibrosis which follows produces an equally satisfactory surface.

Simple measures to compress the spread-out tibial plateau by Esmarch bandages, or compression clamps, accompanied by skeletal traction through the tibial tuberosity, or the bone below it, are much more likely to achieve good results than complicated restorative operations, if they can be followed by early non-weight bearing exercises.

The collateral ligament injury which may be associated, can on the other hand always be profitably explored and sutured.

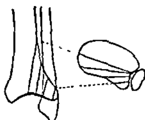


Fig. 578. Posterior marginal fracture of the tibia merges into fracture of the posterior tubercle.



Fig. 579. The mechanism of posterior marginal fracture by compression. Even after reduction, damage to the articular surface remains.

The fractures met with may be .—

1. Fracture of the outer margin of the tibial plateau.
2. Depression of one half of the tibial plateau.
3. Depression and comminution of one half of the tibial plateau.
4. Compression of the tibial plateau as a whole, with possibly a few undisplaced fissures
5. Gross compression and disorganisation of the plateau.
6. Depression of one half of the plateau, leaving the outer margin of the tibia intact, surrounding it.

Fractures involving the outer edge of the tibial plateau. In these fractures the ligaments are intact, the outer condyle of the femur having merely pressed on the outer margin of the tibia. The outer margin of the tibia is only attached to the coronary ligaments, and is better replaced by *temporary compression of the whole of the tibial plateau* by winding an Esmarch bandage round the knee firmly, than by forced adduction or abduction of the tibia. The depression is usually small (Fig. 576) and the main part of the tibial plateau remains undamaged. The lesion may be accompanied by damage to the associated cartilage.

Treatment. This consists of aspiration of the joint, the use of a compression bandage where needed, and the support of the joint by a Robert Jones compression bandage. After a few days quadriceps exercises are begun and at the end of a week non-weight bearing exercises started. Should early

should be commenced from the first, and is best applied through a pin in the lower end of the tibia. A pin in the calcaneus is in this case less satisfactory. The leg is held on a Thomas splint in extension, the knee joint being aspirated and surrounded with a compression bandage. A pull of 10 lbs. is used to commence with, and is increased or decreased according to the change seen in the radiographs. At the end of two days the case is reviewed. In a few cases the traction will have settled the condyles in fair position, but in the majority it must be aided by compression with a clamp.



Fig. 582. A comminuted fracture of the upper end of the tibia, showing marked displacement.

This is applied for a moment and screwed tight, being immediately released. A control X-ray is taken and if satisfactory the knee is firmly bandaged and replaced on the Thomas splint in extension. In order to retain some mobility in the joint early flexion and quadriceps exercises are essential, and these are commenced after the second stage, when a pin through the tibial tuberosity, or below it if it is involved in the fracture is inserted in place of the lower tibial pin. This nail is removed about the end of the fourth week, and non-weight bearing exercises with the support of a Robert Jones bandage continued. Weight bearing will not be allowed till between the twelfth and sixteenth week, and only if there is good, muscular control.

At the end of ten to twelve weeks the patient is fitted with a walking calliper and allowed out. The calliper is worn for six to nine

margin of the condyle (Fig. 569). This fracture is inevitably accompanied by damage to the collateral ligament but the fibula may remain intact. Damage to the tibial plateau on the medial side of the fracture occurs and the surface is depressed here. Reduction of this type of fracture is similar to that described above the small depressed area described remaining unreduced (Fig. 579). Lateral compression is usually sufficient to reduce it if combined with adduction. Operative treatment is rarely necessary, nor is the introduction of pins laterally through the condyle and into the tibial substance to lever up the condyle needed.

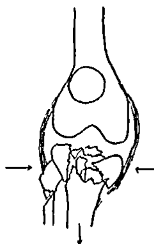


Fig. 580. A comminuted fracture of both condyles of the tibia, indicating the directions of application of force to restore approximate position of the fragments (compare Fig. 582).

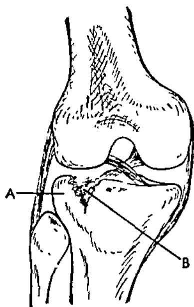


Fig. 581. Depression of the articular surface of the tibia (B) leaving an intact outer wall of the tibia (A).

Where the plateau fails to split, comminution and depression of the plateau occurs. This may leave an intact margin as shown in Fig. 581, or the whole condyle may be grossly comminuted with inevitable damage to the meniscus. In these cases the collateral ligament will often be found intact,

or successful [illegible]
of a blood supply and lie poorly supported by other fragments. More damage is likely to be done by the operation than good. Comminuted fractures may therefore be divided into two groups, those in which an approximately normal appearance can be restored by the measures described above and those in which no satisfactory restoration can be accomplished. In these last cases open operation to remove fragments which would block extension is desirable.

Comminuted fractures of both condyles. Such fractures can only be reduced by a combination of traction and compression. Traction

plateau is not as a rule displaced, though it may be involved by fissuring into it. Displacement in non-compound cases is small.

TREATMENT. Impacted cases should not be disimpacted unless there is gross deformity and shortening. The impaction gives one the opportunity to concentrate on function of the knee without weight bearing for the first month. The limb is supported on a slung Thomas splint or in a plaster gutter splint, during this period. Having obtained a reasonable degree of knee movement, the immobilisation of the knee in plaster to allow weight bearing from the fourth week on need not be feared. A knee fixation plaster leaving the foot free is sufficient. Union is rapid, being firm in eight to ten weeks.

In non-impacted cases the alignment of the limb is corrected and maintained by a complete plaster cast from foot to groin. Active quadriceps drill is commenced from the beginning. If there is an effusion into the knee this should be aspirated before the application of the plaster. As soon as there is any evidence of commencing union the knee fixation plaster leaving the foot free is applied and weight bearing commenced. In the later weeks this may be guttered for the commencement of knee flexion exercises. Rarely in these cases is shortening a consideration, but if present the methods employed in fractures of the shaft of the tibia should be utilised in its correction.

One danger of fractures in this region requires to be mentioned. The posterior tibial vessels are held firmly in position as they pass under the fibrous origin of the soleus. They cannot consequently avoid the pressure of fragments of bone displaced posteriorly, or of excessive tension in the region. These fractures may therefore be followed by arterial obstruction of varying degree and paralysis of the posterior tibial nerve. This is one manner in which Volkmann's contracture of the leg may arise. Should the condition be recognised the vessels should be decompressed by a posterior incision exposing them.

FRACTURES OF THE SHAFT OF THE TIBIA

This fracture is not common as the sudden loss of the support of the tibia throws a heavy strain on the fibula which consequently fractures. It is therefore most likely to be seen where the fracture of the tibia is incomplete or permits little displacement, or in which the fracturing force has ceased to act after impact with the bone. A kick at football is a not uncommon method of producing a transverse fracture, often with minimal displacement. The fractures of the tibia alone commonly met with are :—

1. *Greenstick* fractures in children up to the age of fourteen (Fig. 584). In them there may be very little to note except the

months. With such cases perfect knee function cannot be expected, but it is often surprising what movement returns to an apparently completely disorganised knee. The development of a late arthritis is almost inevitable, but a young patient may have many years good use out of a knee before this occurs.

The importance of treating all knee injuries in the extended position cannot be over-emphasised. It gives accurate control both



FIG. 583 Fracture of the upper third of the tibia and fibula

by vision and by X-ray over the fragments and the position of the joint In the case of injuries to both condyles, if treated in flexion, the posterior displacement of the tibia on the femur is likely to be overlooked, but is easily seen in the extended knee, and adduction and abduction can be accurately controlled.

Fractures below the tibial plateau. These are most commonly the result of direct violence below the knee, though they may occasionally be the result of leverage and impaction of the cancellous bone of the condyles over the compact bone of the shaft. The tibial

plateau is not as a rule displaced, though it may be involved by fissuring into it. Displacement in non-compound cases is small.

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Fig. 584. Spiral fracture of greenstick type not uncommon in children.

child's reluctance to use the leg, local pain, and a history of injury. The lesion is revealed by radiography.

2. *Transverse* fractures without displacement. Usually due to blows and therefore sometimes compound. Angulation is to be feared if too early weight-bearing is permitted. Some weeks in a non-weight-bearing plaster is therefore necessary before this is allowed and a well-fitting plaster is essential. Union is slower than in helical or oblique fractures, but more rapid the nearer the fracture is to the ends of the bone. Firm union should be established in an adult in twelve weeks and in a child it may occur in half this time.

3. *Oblique* fractures, being due to strong bending violence, usually involve the fibula as well, and are treated in the same manner as a spiral fracture, the prevention of shortening and angulation being the chief concern.

4. *Spiral* or helical fractures with little displacement may occur, the elasticity of the fibula and its attachments permitting the tibia to be broken before it yields. Shortening in such cases is minimal, but there may be angulation of the tibia towards the fibula. Even if not present at once it frequently occurs during treatment and a fracture from which a good result is anticipated may be disappointing. A second factor which is more difficult to correct is rotational deformity. This must be carefully watched for and checked clinically and radiologically whatever method of retention is employed. For this reason operative fixation with one or two screws, which with the slight displacement present is a very simple procedure, is to be recommended if there is any displacement. If this cannot be carried out the fracture should be controlled by a long leg plaster and weight-bearing avoided for four to six weeks, when it should be permitted in a fresh well-fitting plaster.

In fresh fractures the usual precautions in applying a complete plaster must be observed If it is thought desirable to encircle the limb an even padding of cotton wool should be applied under a bandage. More satisfactory is the use of a wide unpadded slab bandaged on to the back of the limb and leaving a gap of three inches in front which can be split down easily if swelling is likely or œdema

appears. It must not be forgotten that it is occasionally convenient to apply the slab to the front of the limb, *e.g.*, when lacerations or abrasions of the calf exist.

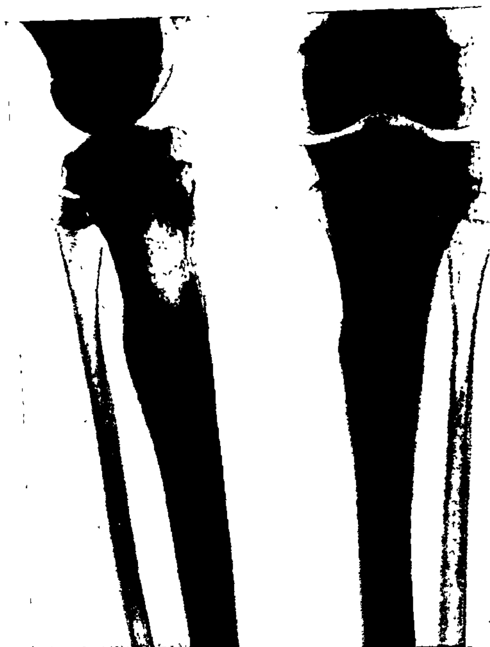


Fig. 585. Fatigue fracture of the tibia Note increased density at site of fine fissure fracture, and sub-periosteal new bone formation.

FATIGUE FRACTURE OF THE TIBIA

The yielding of bone to repeated stress without the history of a severe injury has now been recognised in many situations other than the metatarsals in which it was first described as " march fracture." Among the sites where it occurs are the neck of the femur, the lower

third of the femur, the humerus, the first rib, and the upper third of the tibia. For the fracture to be classed as a fatigue or stress fracture it must be possible to trace it through three stages :—

1. Subperiosteal deposition of bone, without fracture.
2. Fissure fracture, with increased density on either side of the fracture line.
3. A healed stage with increased thickness of bone.

The first two stages are characteristically shown in Fig. 585, which shows a fatigue fracture of the tibia in one leg. The opposite tibia subsequently showed a similar series of changes. The condition is met with in adolescents undergoing severe exertion, *e.g.*, army training. The complaint is one of local pain aggravated by exertion and may be bilateral. Clinically there is local tenderness and swelling. The diagnosis is based on the radiological findings in the absence of an adequate history of injury. Treatment depends on the stage of the condition. In the acute phase it is usually sufficient to avoid over exertion on the legs till the healed stage is apparent. Owing to the fact that periosteal new bone formation may even precede the appearance of the fracture line, no danger of spontaneous fracture need be feared. The cause of the condition in the tibia runs approximately three months. Graduated physical training may then be recommended.

Fractures of the lower end of the Tibia. These are more profitably discussed with fracture of the ankle. but may be summarised here.

1. Supra-malleolar fractures, not involving the ankle joint (Fig. 577).
2. Compression fractures of the lower end of the tibia, with angulation or fissures running into the ankle joint.
3. Rotational fractures of the lower end of the tibia, one fissure from fracture frequently entering the ankle joint. (The fracture pseudo-spiroidale *of Gosselin.)*
4. Fracture of the medial malleolus (see page 606).
5. Fracture of the posterior margin of the tibia (see page 538) (Fig. 578).
6. Fracture of the tibial tubercles and the tibial gutter (see page 570).
7. Anterior marginal fractures of the tibia (see page 608).
8. Epiphyseal separations. These may be accompanied by separation of the fibular epiphysis, but as the tibial separation dominates the picture they will be discussed here.

Supra-malleolar fractures. Such fractures are the result of direct violence in adults, but in children they are often due to indirect violence. In these cases the relationship of the bony points around the ankle will be normal unless the fracture has run down into the joint, and abnormal mobility will be elicited above the joint level. If the joint surfaces are not involved the outlook is good, as it is easier at this level to restore the correct alignment

of the leg. Union is rapid. Frequently the fracture line is oblique, but in spite of this reduction by manipulation and retention by plaster alone is possible. Occasionally one has to use skeletal traction through the calcaneus.

Separation of the lower tibial epiphysis. Complete or incomplete separations are not uncommon in children occurring up to the age of sixteen years. Usually a wedge-shaped portion of the diaphysis accompanies the epiphyseal fragment. The common directions of displacement are medial, anterior and posterior. The presence of the fibula prevents lateral displacement, though this may occur if accompanied by fracture of the fibula.



Fig. 586. Lateral displacement of the tibial epiphysis, with a lateral marginal fracture of the tibial metaphysis and a fracture of the fibula.

Manipulative reduction is usually simple, the epiphysis being forced back in the appropriate direction by the pressure of the palm. In posterior displacements it is often easiest to turn the patient over on his face and reduce the deformity over a wedge (Fig. 589). After reduction a plaster slab is applied and control radiographs taken.



Fig. 587. Fracture separation of the lower tibial epiphysis. The posterior dis- ... an ... , and



Fig. 588. The same case after reduction.



FIG 589. Reduction of a posterior displacement of the lower tibial epiphysis over a padded wedge.

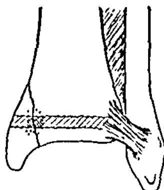


FIG. 590. The epiphyseal line at the lower end of the tibia showing how it is involved in adduction fractures, and the medial malleolus, which may lead to premature synostosis where the fracture crosses the epiphyseal plate.



FIG. 591 Uneven growth of the tibial epiphysis after a fracture of second
a vertical fracture of the
the tip of the fibula which

If these are satisfactory, as soon as swelling has subsided a walking plaster is applied. Union is firm in six weeks.

On rare occasions the epiphysis may be fractured in the centre from compression violence. There is little separation as a rule, and the treatment is similar. With severe adduction strain the medial malleolus may be separated from the epiphysis, often taking a small metaphyseal chip with it. The lesion resembles a first degree adduction fracture and if displaced is treated in the same manner (Fig. 653).

Interference with growth rarely follows this fracture but may occur (Fig. 591). It is more common following compression lesions of the epiphysis. In each case the mechanism is the same, premature synostosis of both sides of the plate occurring at the site of fracture and restricting growth at this area.

FURTHER READING

Upper End

CUBBINS, CONLEY and SIEFFERT. "*Fractures of the Lateral Tuberosity of the Tibia, with Displacements of the Lateral Meniscus between the Fragments*." *Surg. Gynæ. and Obstets.*, 1929, 48, 106.

PALMER, I. [illegible] Treatme[illegible]

CLARKE, Fr[illegible] Tibia inv[illegible]

COTTON. "[illegible]

ELIASON and EBELING. "Non-operative Treatment of Fractures of the Tibia and Femur involving the Knee," *Surg. Gynæ. and Obstets.*, 1933, 57, 658.

CAVE, E. F. "Fractures of the Tibial Condyles Involving the Knee Joint," *Surg. Gynæ. and Obstets.*, 1948, 86, 289–294.

FAIRBANK, T. J. "Condylar Fractures of the Knee Joint," *Proc. Roy. Soc. Med.*, 1955, 48, 95.

PALMER, I. "Fractures of the Upper End of the Tibia," *J. Bone and Joint Surg.*, 1951, 33B, 160.

BRADFORD, C. H. *et all.* "Fractures of the Lateral Tibial Condyle," *J. Bone and Joint Surg.*, 1950, 32A, 39.

Fatigue Fractures

PROCTOR, CAMPBELL and DOBELLE. "March Fractures of the Tibia and Femur," *Surg. Gynæ. and Obstets.*, 1944, 78, 415.

BURROWS, H. J. "Fatigue Fractures of the Fibula," *J. Bone and Joint Surg.*, 1948, 30B, 266–279.

CHAPTER XXX

FRACTURES OF BOTH BONES OF THE LEG

Of all the long bones the tibia is the most commonly fractured. Injuries to the leg are particularly frequent under modern industrial and traffic conditions, and because of the subcutaneous nature of the bone they are commonly compound, either directly or indirectly. The position of the bone lying, as it does, between the two hinged joints of the ankle and the knee is peculiar. These joints are carefully aligned by nature in their axes of movement, and the slightest disturbance of the alignment of the bone results in a redistribution of strain through the knee and ankle which, if severe enough or *existing long enough, will eventually produce a traumatic arthritis* at one or both joints. It is only in the young, where the continuation of growth will result in spontaneous rectification of any malalignment, that the results of fracture of the leg can be treated lightly. In the adult though the immediate results may be gratifying, the late results are [illegible]
men the average fracture [illegible]
tion in physical efficiency. [illegible]
effects of imperfect alignment. In some cases soft tissue damage and adhesions are in part responsible, particularly in infected fractures; while too long continued traction and inefficient immobilisation take their toll. It is nevertheless true that fractures of the leg bones being regarded as simple to treat, are in fact more unsatisfactory in the long run than many more complicated injuries. The introduction of skeletal traction, while it has improved immensely the position achieved in fractures of the leg, has brought with it many disadvantages. These may be summarised as follows :—

1. Over traction and stretching of ligaments at the primary reduction.
2. The continuous use of traction with continuous ligament stretch.
3. Continuous over-traction with delayed union.
4. Fixed distraction with two pins, with greater chances of non-union.
5. The dangers of pin sepsis near a joint.

Prolonged immobilisation without adequate movement of the knee or the ankle is undesirable in all cases, and it is not true to state that if the patient is weight-bearing on the immobilised limb it is unimportant. Active use of the limb in plaster is to be recommended wherever possible, and it does reduce stiffness to a great

extent. It is not, however, comparable with a method which leaves the joints free for exercises.

The ideals of treatment of fractures of the leg must thus be :—

1. Perfect reduction. Both angulation and shortening are to be corrected, but rotation which is commonly neglected is equally important.

2. The avoidance of traction in any form if possible, and if it must be used, only as a method of immediate reduction and not of retention.

3. The earliest use of the knee and ankle joints possible without risk of loss of alignment.

4. The use of the limb for weight-bearing as soon as possible.

It would seem that these ideals can only be satisfied by open operation and internal fixation. This method, though probably adding a fortnight to the time taken for clinical consolidation of the bone, is the ideal under good operative conditions and in experienced hands.

Ætiology. Rotational violence produces helical or spiral fractures of both bones, the fractures sometimes being at the same level, but more frequently the fibula fracture is higher up, and may be missed if the X-ray film fails to include the upper end of the bone. These fractures tend to be indirectly compound, a sharp spicule of bone penetrating the skin over the subcutaneous border of the tibia. Direct violence usually produces a transverse fracture of both bones at the same level, and the fracture is often directly compound. Comminution may occur. Bending violence may produce double oblique fractures by the mechanism shown on p. 5. In all cases of fracture of both bones of the leg temporary splintage is more important than elsewhere owing to the great displacement which may occur and the possibility of this rendering the fracture compound.

Diagnosis These cases present the classical signs of fracture and present no difficulties. Bruising is very variable, and may be immense. Injury to nerves is almost unknown, but injury to blood vessels is more common, and may account for a few cases of gangrene of the toes following fracture. Shortening and angulation are the most common displacements, but with rupture of the interosseous membrane it is possible for the bones to be widely separated.

Treatment This may be outlined in a skeleton manner as follows. It is very largely dependent on the direction of the fracture line.

Transverse . .	Manipulation and plaster gutter splint. Early walking plaster (*i.e.*, in 10 to 18 days). Plating.

Type of fracture	Treatment
Slight obliquity . Part oblique, part transverse (Fig. 7) .	Screw fixation. Plating. Manipulation and gutter splint. Walking plaster a little delayed (3–4 weeks). Angulation often best corrected at the end of ten days.
Spiral or helical (Fig. 4) Oblique (Fig. 3) . Comminuted (Fig. 13)	Screw fixation. Plating. Continuous traction in plaster to commence with then a complete plaster. Walking plaster considerably delayed till callus firm and shortening cannot occur (4–6 weeks).

Transverse fractures. (*a*) WITHOUT DISPLACEMENT. In the absence of any risk of shortening treatment becomes simple. As a preliminary a posterior plaster slab is applied encircling two-thirds of the limb. A simpler substitute for this is a well-moulded Cramer wire splint, which with side pieces may be strapped to a Braun's splint. The limb is elevated until swelling has subsided, when a complete circular plaster is applied from the thigh to the toes. The plaster may stop at the metatarsal heads leaving the toes free to exercise. The patient is encouraged to get about on crutches, and at the end of the fourth week a fresh close-fitting plaster is applied and weight-bearing permitted. This is best done through some form of shoe taking the weight on heel and toe through a sponge-rubber sole. Some softening of the sole of the plaster is no disadvantage as it allows more normal metatarsal movements. Careful radiological control is maintained to prevent angulation, and if this occurs it can best be corrected by wedging the plaster. The continuation of the plaster above the knee may not always be necessary in fractures of the lower third of the bone. Union should be clinically firm in ten to twelve weeks when the plaster should be removed and active rehabilitation begun.

(*b*) WITH DISPLACEMENT. Displacement can often be reduced by manipulation under anæsthesia alone. Such cases are treated after reduction in the same way as undisplaced fractures. Swelling and s [illegible] tly the date [illegible] Where reduc[illegible] Böhler or Watson Jones traction frame is necessary. Skeletal traction is applied through the os calcis or the lower end of the tibia (preferably the former) and the fracture disimpacted and reduced. Radiological control before the application of a plaster may be helpful. Care must be taken that the rotation of the foot is correct, and the interdigital

cleft between the first and second toes is in line with the mid line of the patella.

The leg is then plastered on the frame. The Kirschner wire or pin is removed and in high fractures of the shaft the plaster continued above the knee with the knee in slight flexion. A displacement of a quarter of the width of the tibial shaft can be neglected if the alignment is good. This is controlled by wedging later if necessary. If a non-padded plaster cast has been used it should be split down the antero lateral aspect. Alternatively, light padding may be

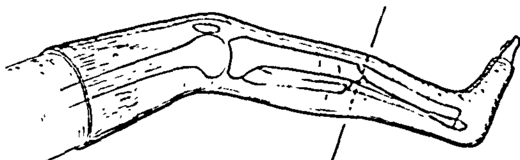


FIG. 592. Angulation of a fracture in plaster

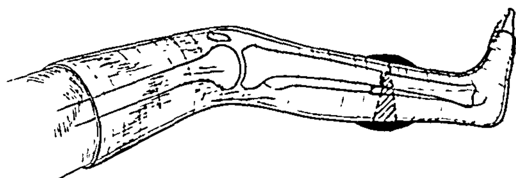


FIG. 593. Correction of the angulation by division of the plaster at level of the fracture with a saw and opening up the plaster. (Wedging the plaster.)

included around the fracture area to allow for swelling. The patient will be more comfortable if the limb is slung. This is most easily done by putting a Thomas splint over the limb and attaching it by a double cuff of plaster. The after-treatment is similar to non-displaced fractures once the swelling has subsided and early union has prevented the possibility of lateral displacement of the bone. The plaster need only be maintained above the knee if the fracture is in the upper two-thirds of the bone and in the early stages of treatment.

(c) WITH IRREDUCIBLE DISPLACEMENT. This is uncommon, but fractures may get locked out of position by soft tissues or by fragments of bone. After attempts at reduction have failed by the

Slight obliquity . Part oblique, part transverse (Fig. 7) .	Screw fixation. Plating. Manipulation and gutter splint. Walking plaster a little delayed (3–4 weeks). Angulation often best corrected at the end of ten days.
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(*b*) With displacement. Displacement can often be reduced by manipulation under anæsthesia alone. Such cases are treated after reduction in the same way as undisplaced fractures. Swelling and soft tissue injury is likely to be greater, and consequently the date on which a close-fitting plaster can be applied is delayed. Where reduction is not satisfactory by manual methods the use of a Bohler or Watson Jones traction frame is necessary. Skeletal traction is applied through the os calcis or the lower end of the tibia (preferably the former) and the fracture disimpacted and reduced. Radiological control before the application of a plaster may be helpful. Care must be taken that the rotation of the foot is correct, and the interdigital

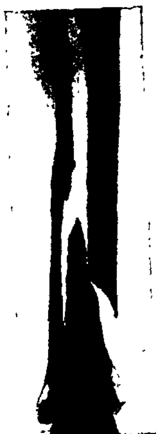


Fig. 594. Spiral (helical) fracture of both bones of the leg—due to external rotation violence.



Fig. 595. Perfect reduction of previous case with a single screw.



Fig. 596. Skeletal traction in reduction of a fracture of the leg—ready for plastering. (Hawley Scanlon table.)

Some form of skeletal traction is necessary for reduction and continuation of traction is usually necessary for retention, as there is a tendency for the leg to shorten inside the plaster as the swelling

ordinary method open operation should be carried out. The alternatives presenting themselves then are interlocking of the bone ends without fixation, light plating and external splinting, and heavy plating without external support. This is a matter for decision on the conditions present and personal preference. Transverse fractures can occasionally be maintained in position by an oblique screw.

Oblique fractures. In this group of fractures lateral displacement and shortening and angulation are likely to occur. This includes fractures from bending violence, fractures in which the fracture line is half oblique and half transverse (Fig. 7), and fractures in which a butterfly fragment has not fully separated (in other words, a half oblique, half transverse fracture in which the oblique fragment is incompletely separated by a fissure). These cases lend themselves to simple measures of operative fixation with perfect reduction of the fracture, and this is to be recommended where conditions are satisfactory. A single or double screw may be used and a moderate degree of stability achieved. These fractures are not uncommonly indirectly compound and immediate operative fixation may well be combined with excision of the wound. Where there is risk of infection it is not yet certain whether the introduction of even the minimal amount of metal is justifiable. It is probable, however, that a single screw can do little harm in an open wound.

Spiral or helical fractures. Provided that there is no comminution of the sharp ends of the bone these fractures lend themselves particularly to fixation by screws. The fracture is so shaped (Fig. 4) that it interlocks firmly, and provided it cannot be rotated it resists deformation. It is therefore very convenient to treat these cases by single or double screw fixation in the manner previously described. A rigid limb is obtained which can be given exercises very early and in which it is unnecessary to use a plaster cast. If early weight bearing is desired a walking plaster may be applied between the fourth and the sixth week Consolidation takes ten to twelve weeks.

At operation definite evidence of the difficulties of non-operative reduction may be seen in the form of displaced fragments of bone or interposed soft tissues. Perfect reduction by any other method except in cases where the fracture is subperiosteal and needs only closing by the correct rotation of the foot is almost impossible. Similar observations apply to oblique and half-oblique fractures.

Non-operative Reduction of Oblique and Transverse Fractures

The difficulty in these cases is the prevention of shortening. Angulation and rotation can be controlled more easily and are both important, particularly rotation which is apt to be neglected.

starts, about the sixth week, the upper pin may be removed and a fresh weight-bearing plaster applied.

Continuous traction. This is an alternative method by which the

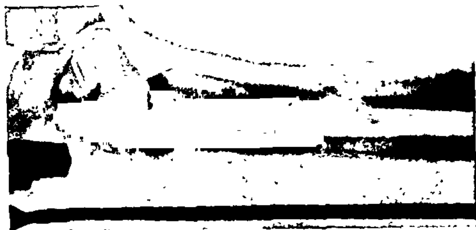


Fig. 598. An oblique fracture of the shaft of the tibia, with a fibula fracture higher up, under treatment by skeletal traction in the calcaneus, the whole leg being supported in a light plaster.

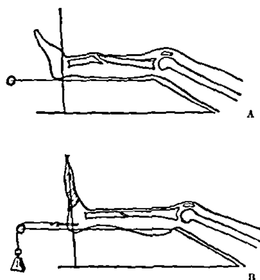


Fig 599. A. The malposition developed in an unsupported leg lying on a Braun's splint B The position correctly maintained by traction, support to the foot, and the correct bandaging of the splint, so that the calf can sag a little into the bandages Foot drop is prevented by strapping based along the sole of the foot, over the transverse bar, and along the dorsum, and bandaged on.

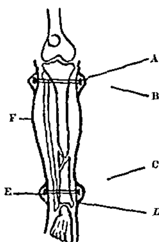


Fig. 600. The method of securing a comminuted fracture of the tibia by double pinning. A. Collar on upper pin. B. and C. Upper and lower Steinmann's pins. D. Plaster covering lower pin. E. Collar on lower pin to prevent rotation. F. Walking plaster.

effect of the upper pin is replaced by a continual pull on the leg. It is undesirable if the pull is taken through the os calcis, as the ankle joint is then under continuous tension and considerable stiffness of

subsides. In order to overcome this the use of two pins incorporated in the plaster has been suggested. This method, though excellent for retention, is apt to produce permanent distraction of the fragments with resultant delay in union. More satisfactory is the use of one pin through the plaster and tibial tuberosity to prevent sliding of the plaster on the leg and the control of the lower fragment by the plaster around the foot. Less forcible distraction is likely to result if this is done. Reduction is carried out on the Braun's frame by means of a wire through the os calcis or the lower end of the tibia. Shortening can usually be corrected by clinical observation, but if



FIG. . . . duction of a
. trol of the

there is any doubt radiological control should be sought. The tibial tuberosity is transfixed by a Steinmann's pin and the foot and both pins and wire incorporated in the plaster. If the fracture is fresh and swelling is anticipated a thin cotton wool padding should be employed. In any case a turn of flannel bandage should be taken around the malleoli and over the dorsum of the foot which are liable to pressure. The Kirschner wire is removed from the heel and the leg rested on a Braun's splint. Correction of rotation and angulation may be made by making a circular cut through the plaster at the level of the fracture, and either rotating the lower fragment or wedging the plaster. The patient is able to get about on crutches, the plaster being continued above the knee if the fracture is in the upper third of the tibia. As soon as consolidation

and treatment of shock the better. Here, when under the anæsthetic, the clothes are removed and the wound prepared. The technique is described on p. 80. The limb is wrapped in a sterile towel and an Esmarch bandage applied to exsanguinate the limb, and a second Esmarch as a tourniquet. The wound is then excised in the usual manner and the open reduction of the fracture by the use of Lane's forceps and manipulation proceeded with. Inspection of the fracture ends determines the correct position of the screw or screws which should run as far as possible at right angles to fractured surfaces. A drill hole, one sixty-fourth of an inch smaller than that of the screw, is made in the correct direction and followed by a screw. A second screw is inserted if necessary. The periosteum and soft tissues are drawn together by a few interrupted stitches and the skin carefully closed. In the leg hæmostasis is usually satisfactory, but elsewhere the tourniquet should be released and hæmostasis established. If any uncertainty remains a drain should be inserted for twenty-four hours. The limb is then firmly wrapped in a thin layer of cotton wool and bandaged. Over this a light plaster cast is carried up to the knee and the limb is rested on a Braun's splint.

AFTER-TREATMENT. This is very variable and the variability is due to the need to balance the demands for external support against the desire to exercise the leg early. The factors chiefly concerned will be :—

1. The shape of the fracture.
2. The level of the fracture.
3. Internal fixation.

} *i.e.*, the stability of the fracture.

Other factors, such as associated injuries, the age of the patient, the muscular control of the limb and the patient's sense of balance, will have to be considered.

A characteristic progression after fixation of an oblique fracture with two screws would be, if the fracture were near the ankle, change of post-operative below-knee plaster and removal of stitches between the fourteenth and twenty-first days, substitution of a well-fitting below-knee plaster, commencement of knee exercises, provision of a plaster overshoe and commencement of weight bearing about the sixth week, removal of plaster at the twelfth week, supporting elastic bandage, and ankle and walking exercises. This might be varied, if the patient had to be recumbent, by the use of a plaster gutter splint which could be removed, after the twenty-first day. This would be removed daily for exercises to knee and ankle. If at the end of the sixth week these were almost full, very little stiffness would follow the use of a below-knee weight-bearing plaster, or even of an above-knee plaster if the fracture was high in the tibia, for the necessary time for sound consolidation to occur.

With a transverse fracture which has been plated much the same routine might be followed. If it were not plated, weight bearing would have to be delayed for a month owing to the risk of angulation at the fracture site, and it would be wise to maintain the limb in an

the joint results. Traction through a pin in the lower end of the tibia is not so open to objection. In both cases knee movements will be restricted by the necessity to continue the plaster above the knee with the knee in slight flexion to control rotation. The weight employed will vary with the individual's weight, being about a tenth of it (10 to 18 lbs.). The weight is gradually reduced till at the end



FIG. 601. An oblique fracture of the tibia, showing the satisfactory position obtained by plaster when the patient was recumbent.

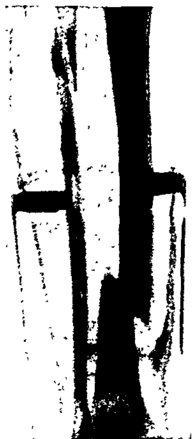


FIG. 602. The same case showing the effects of too early weight bearing in a walking plaster. Note the high fibula fracture.

of the second week it is 5 to 10 lbs. At the end of the third or fourth week there should be no further risk of shortening, unless the fracture has been complicated. The traction is then removed and a new well-fitting above-knee plaster applied. Crutches may then be used and weight bearing with an overshoe permitted between the sixth and the eighth week.

TECHNIQUE OF OPERATIVE FIXATION (see also Chapter VIII). After adequate rest and preparation of the patient (which does not mean complete removal of his clothes, and preparation of the wound area) the patient is taken to the theatre. The sooner this can be done after the infliction of the injury

and treatment of shock the better. Here, when under the anæsthetic, the clothes are removed and the wound prepared. The technique is described on p. 80. The limb is wrapped in a sterile towel and an Esmarch bandage applied to exsanguinate the limb, and a second Esmarch as a tourniquet. The wound is then excised in the usual manner and the open reduction of the fracture by the use of Lane's forceps and manipulation proceeded with. Inspection of the fracture ends determines the correct position of the screw or screws which should run as far as possible at right angles to fractured surfaces. A drill hole, one sixty-fourth of an inch smaller than that of the screw, is made in the correct direction and followed by a screw. A second screw is inserted if necessary. The periosteum and soft tissues are drawn together by a few interrupted stitches and the skin carefully closed. In the leg hæmostasis is usually satisfactory, but elsewhere the tourniquet should be released and hæmostasis established. If any uncertainty remains a drain should be inserted for twenty-four hours. The limb is then firmly wrapped

, is

AFTER-TREATMENT. This is very variable and the variability is due to the need to balance the demands for external support against the desire to exercise the leg early. The factors chiefly concerned will be :—

1. The shape of the fracture.
2. The level of the fracture.
3. Internal fixation.

} *i.e.*, the stability of the fracture.

Other factors, such as associated injuries, the age of the patient, the muscular control of the limb and the patient's sense of balance, will have to be considered.

A characteristic progression after fixation of an oblique fracture with two screws would be, if the fracture were near the ankle, change of post-operative below-knee plaster and removal of stitches between the fourteenth and twenty-first days, substitution of a well-fitting below-knee plaster, commencement of knee exercises, provision of a plaster overshoe and commencement of weight bearing about the sixth week, removal of plaster at the twelfth week, supporting elastic bandage, and ankle and walking exercises. This might be varied, if the patient had to be recumbent, by the use of a plaster gutter splint which could be removed, after the twenty-first day. This would be removed daily for exercises to knee and ankle. If at the end of the sixth week these were almost full, very little stiffness would follow the use of a below-knee weight-bearing plaster, or even of an above-knee plaster if the fracture was high in the tibia, for the necessary time for sound consolidation to occur.

With a transverse fracture which has been plated much the same routine might be followed. If it were not plated, weight bearing would have to be delayed for a month owing to the risk of angulation at the fracture site, and it would be wise to maintain the limb in an

above-knee plaster a little longer. The variations in progression are innumerable and may be as individual as the fractures themselves.

Special difficulties with Fractures of both Bones of the Leg

Due to the fractures :—

1. Comminution.
2. Rotation of a fragment with skin pressure.
3. Entry into the knee or ankle.
4. Double fractures.

Due to the involvement of soft tissues :—

1. Burns and abrasions over the fracture.
2. Compound fractures (see Chapter IX).
3. Skin loss (see Chapter IX).
4. Gross swelling of the limb.
5. Skin necrosis from pressure of bone, blood or causative violence.

Most of these points have been enlarged on elsewhere, but a few will be touched on here.

Comminuted fractures. The problem is usually essentially the same as that of an oblique fracture, but slightly increased difficulty is met with due to the greater loss of lateral stability. Occasionally a comminuted fracture of the type shown in Fig. 604 is met with, or a double transverse fracture in which shortening is not much in evidence and which can be controlled by a simple plaster cast. More commonly reduction by skeletal traction and pin transfixion of the upper fragment is necessary.

The grossly comminuted fracture is unsuitable for open operative reduction (Fig. 53). Non-union is an uncommon sequel, comminuted fractures usually consolidating well. In the butterfly type of fracture, in which one large fragment is lying free, operative fixation by double screws (Fig. 606) may be desirable. Comminution

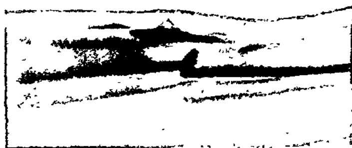


Fig. 603. The dangers of rotation of a fragment of tibial shaft. A rotated fragment such as that shown will ulcerate the skin and eventually produce infection of the fracture. Open reduction and its removal is indicated.

is often combined with an open wound and excessive removal of loose bone fragments should be avoided. Even if the larger fragments are completely detached they should be left, as they encourage the formation of new bone.

Rotation of a bone fragment. Because the tibia is subcutaneous the pressure of a fragment of bone, especially if it is pressing against a plaster, may be dangerous (Fig. 603). Such fragments must if necessary be excised.

Double fractures. Such fractures are common in motor-cycle



FIG. 604 A double fracture of the tibia. This is a typical "fender" or "bumper" fracture. The lower fracture usually suffers the greatest interference with its blood supply, and union is delayed or fails to occur.



FIG. 605. The same case treated by a single screw through the upper fracture. Ordinarily this would be sufficient, the lower fracture then being treated by skeletal traction and plaster to avoid the risks of further interference with the blood supply. In this case the lower fracture was compound, and fixation was employed to stabilize the tissues for plastic procedures on the skin to close off the fracture.

accidents or other injuries in which the central third of the tibia is struck with an object such as a car bumper. The result of the fracture is to isolate the central third of the tibia or the portion of bone lying between the two fractures from its medullary blood supply. It remains dependent on the periosteal blood and its lateral adhesions. Not surprisingly partial avascular necrosis is common, and if the fragment is widely stripped at open operation there is a grave risk that this will become total. After a double fracture union at one fracture is always delayed. Generally it is the fracture distant from the nutrient artery; thus in the tibia the upper fracture unites and the lower fracture fails to unite, though this rule may be altered by local conditions, such as loss of substance, subacute infection and the like. Absolute non-union may be established, and the isolated fragments of bone show increased density compared with the nearby bone, characteristic of avascular necrosis (Fig. 26).



FIG. 606 The double oblique (or butterfly) fracture of the tibia, with a fracture of the fibula high up, treated in plaster with continuous traction.

The ideal treatment is manipulation and plaster. Because of the double fracture usually one fracture only can be dealt with effectively in this manner. It is thus necessary to expose one fracture and reduce it and fix it at the same time. The method demanding the minimum stripping of bone should be employed, and this is usually the single-screw. Where one or both fractures are compound the opportunity to fix one or both should be taken, as this can add little to the risk of avascularity, though once again minimal disturbance of soft tissue adhesions should be the aim.

Compound fractures. Compound fractures of the leg are particularly common. They may be indirect compound fractures from the perforation of the skin by a sharp spicule of bone. Should the spicule be seen externally and be small it may be advisable to cut it

off before excising the wound in the usual manner. Indirect compound fractures (which was the injury from which Percivall Pott himself suffered) have a good prognosis as far as infection is concerned, and adequate excision of the wound should result in all of them healing by first intention. Operative fixation of such fractures can thus be safely undertaken at the time of operation.

Gross compound fractures are treated on the lines previously described. Owing to the subcutaneous nature of the bone drainage is usually satisfactory and dependent drainage seldom necessary. Immobilisation of such fractures must be complete and the plaster must extend above the knee. If there is danger of shortening continuous skeletal traction may be employed, or if there is no risk in insertion a pin should be put through the tibial tuberosity. Elevation of the leg is important and the patient should be made comfortable by slinging the leg on a Thomas splint rather than resting it on a Braun's splint.

For comfortable transport an above-knee plaster should be attached by plaster to the sidebars of a Thomas splint, and the Thomas splint suspended from a crossbar on the stretcher.

Skin loss and swelling. Skin loss has already been fully discussed. In run-over injuries additional difficulties may be met with in the wide stripping of the skin and subcutaneous fat from the superficial fascia, with the collection of a hematoma between the two layers. This may need incision and drainage. The vitality of parts of the skin may be jeopardised by the isolation from a good blood supply or by the crushing of the skin vessels followed by thrombosis. Such doubtful skin areas must be carefully watched, and the appropriate steps taken.

The swelling of the leg after a crushing injury may be so great that whether there is skin loss or not it may prove impossible to close the skin wounds. The same steps must be taken then as when there has been skin loss (p. 123).

Fractures of both bones of the leg in children. These fractures are commonly greenstick and in the milder case it may be sufficient to keep the child off its feet until it shows a desire to get up on them again. In more painful cases a plaster cast to the knee is necessary. In most other fractures a satisfactory position can be obtained by manipulation and plaster. Minor degrees of deformity can be neglected as they will be corrected by growth. The plaster should in all cases be carried above the knee as no danger of stiffness is present and children soon loosen any plaster.

Difficulties with fractures of both bones of the leg. Delayed union. Union is often slow. The best treatment is repeated walking plasters, which may be accompanied in some cases by an osteotomy

of the fibula, which if united may be holding the tibial surfaces apart.

NON-UNION. The junction of middle and lower thirds of the tibia is a classical site for this to occur, and any of the factors mentioned in the general discussion of this subject may be responsible while the treatment is also discussed there (p. 139).

ANGULATION. In late cases this is usually due to too early weight bearing. In recent cases it is best corrected about the tenth to fourteenth day by a fresh plaster and wedging (Fig. 592).

PRESSURE SORES on the heel and malleoli. A small pad of felt may be put over the heel to avoid any risk of this. The malleoli are commonly affected when the traction is released on the heel after the plaster has set. They then displace slightly inside the plaster and develop pressure points. A turn or two of flannel bandage gives sufficient room to avoid this.

EXTERNAL POPLITEAL (PERONEAL) PALSY. This commonly arises from the pressure of the upper rim of the plaster on the nerve. It is avoided if a strip of felt is placed over the head of the fibula and the plaster always continued up to the level of the fibula head and not stopped short over the fibula neck.

FURTHER READING

Shaft

WATSON JONES. "Fractures of the Shafts of the Tibia and Fibula. A New Tibia Traction Apparatus," *J. Bone and Joint Surg.*, 1932, **14**, 591.

CALDWELL. "Treatment of Compound Fractures," *Arch. Surg.*, 1937, **35**, 368.

LOTTES, J. O. *et al.* "Closed Reduction, Plate Fixation and Medullary Nailing of Fractures of Both Bones of the Leg," *J. Bone and Joint Surg.*, 1952, **34A**, 861.

CHAPTER XXXI

FRACTURES OF THE FIBULA

Surgical anatomy. Development. The fibula is the exception to the rule that the centre of ossification first to appear is the last to unite. A primary centre *for the shaft appears* in the seventh and eighth weeks. Secondary centres appear as follow :—

Fibula

Upper end.	In third year.	United before the twenty-fourth year.
Lower end.	In second year.	Unites about the twenty-first year.

The prime function of the fibula is to serve as a spring cushioning strains on the ankle, and giving that firm elasticity to movements in the tibio-fibular mortice on which the smooth function of the ankle depends. It also serves as an additional site for muscular attachments. The most important anatomical relation is the peroneal nerve winding around the neck of the bone. Movements of a millimetre in each direction are permitted at the tibio-fibular syndesmosis, and a variable degree of mobility occurs at the upper tibio-fibular joint. *The fibular collateral ligament and the biceps tendon are* attached to the upper pole of the fibula. Further details of the ligaments are found in the introduction to the next chapter.

Introduction. The Relationship with Fractures of the Ankle

The fractures of the fibula are numerous as the following table shows. They are due to direct violence, in which case they are straightforward and of relatively little interest ; to avulsion of the attachments of ligaments, in which case they are a guide to soft *tissue injury, and to indirect violence, from force applied to the lower* end of the fibula, when they are directly related to ankle injury.

The fractures affecting the ankle are variable and complicated, and the key to their understanding lies in the knowledge of the mechanism of diastasis (or separation of the tibio-fibular syndesmosis,) and the types of fracture of the fibula associated with this injury. If a grasp of these injuries can be obtained before the injuries to the ankle are considered their multiplicity becomes readily comprehensible. A complete discussion of fractures of the fibula, with which must be associated a discussion of diastasis will be used as a preface to fractures of the ankle.

Summary of Fractures of the Fibula

We may commence by dismissing briefly the injuries due to direct violence and avulsion, many of which have already been discussed.

FIG. 607. Summary of Fractures of the Fibula.

Site.	Fibular lesion.	Associated injury.
Upper tip of fibula	Avulsion by the fibular collateral ligament, or insertion of biceps femoris (A).	Rupture of the capsule of the knee joint.
Head of fibula .	Dislocation.	
	Fracture by direct violence.	Skin damage.
	Compression fractures (B).	Depressed fractures of the tibial plateau (Fig. 573).
Neck of the fibula		
	615).	ment.
Shaft :		
Direct violence	Comminuted or bending fracture.	
	Alone.	
	Associated.	Fracture of tibia.
Indirect violence	Wide angulation at fracture (D).	Complete diastasis (Fig. 621).
Upper half.		
Lower third .	Moderate forward angulation (Dupuytren's fracture). High (E) (Fig. 618); low (G) (Fig. 620).	Partial diastasis. The posterior tibiofibular ligament remains intact.
Fibular malleolus	Alone	
Direct violence	Associated.	Fracture of tibial shaft.
Indirect violence	External rotation fracture (first degree) (F) (Fig. 631).	Fractures of the medial malleolus and the posterior margin associated with second and third degree lesions
	Abduction fracture Just above level of tibial plafond (first degree) (H) (Fig. 649)	The above fractures may be associated with second and third degree lesions.
	Adduction fracture. Just below the level of the tibial plafond (first degree) (I) (Fig. 655).	As above.
	Posterior dislocation	
Anterior and posterior tubercles.	Avulsion by the anterior or posterior tibiofibular ligaments (K) (L).	Partial or complete diastasis.
Lower tip of fibula	Avulsion by calcaneofibular ligament (J).	Rupture of collateral ligament of ankle. (Partial or complete.)

FRACTURES OF THE UPPER END OF THE FIBULA. Undoubtedly the most common lesion is the spiral fracture of the neck of the bone due

to rotational violence. In order for the rotational force to pass the limit of elasticity of the bone either the tibio-fibular syndesmosis must be damaged or the tibia fractured. It is possible for the peroneal nerve to be caught in such fractures as it winds round the neck of the bone and to be severely crushed. Displacement of such fractures is minimal and the treatment is that of the primary lesion.

The head of the fibula may be crushed in direct violence by being squeezed against the tibia. The peroneal nerve may therefore be damaged. Treatment in such cases as are not compound consists of rest and the support of a firm bandage.

Where the fibula head is displaced the tibial condyle is usually displaced as well, and with the reduction of the plateau it is brought back into good position. The tip of the fibula corresponding to the attachment of the fibular collateral ligament and the biceps may be avulsed in adduction injuries of the leg as has been discussed before on p. 537. An interesting variation is the fracture of the fibula neck below the insertion of the biceps, which draws the upper fragment backward. The reduction and retention of this fracture is impossible without open operation, spasm of the biceps maintaining the displacement. Fixation of the two bone ends in contact by a loop of wire or strong catgut maintains reduction.

Fractures of the shaft of the fibula. This is due to direct violence, and is frequently transverse. There is no displacement, but a distressing feature is the persistence of pain. It may be the pain which brings a patient to the doctor, when he has considered himself to be suffering from a bruise. The tracking of the blood-staining along the peroneal compartments in such a case should arouse suspicion. Immediate relief of the pain can be produced by an injection of novocaine into the hæmatoma. After-treatment should consist of massage and exercises, or if there is little discomfort on walking, of firm support with elastoplast or a crepe bandage. Though a minor fracture, pain is apt to persist for longer than expected, and can be relieved by repeated injections.

The mechanism of fracture of the fibula by indirect violence. The thin elastic fibula shaft is firmly anchored at both ends and tied down on the medial aspect by the interosseous membrane. It can only be broken indirectly by torsion or by bending, and the forces developing these stresses in the bones can only be applied to the lower end of the bone, where the fibular malleolus projects below the tibial articular surface (the tibial " plafond "). The effect of force applied to this malleolus is to place a strain on the syndesmosis. If the ligaments of this joint remain intact little strain will be felt by the fibula, but if they yield in part or completely then the fibula will be exposed to considerable stress. Fractures of

the fibula are therefore a reflection of the ligamentous damage around the fibular malleolus, and it is as such that they must be considered, for soft tissue injury is equally important to bone injury. The guide to fibular fractures is diastasis, which must therefore be considered first.

The shaft of the fibula can be broken by bending it medially, laterally, anteriorly or posteriorly. If bent medially it presses against the tibia, and this prevents fracture unless the tibio-fibular syndesmosis yields, and this is the common method of rupture of the joint in abduction injuries. If bent laterally it is supported by the interosseous membrane, and the adduction force applied to the

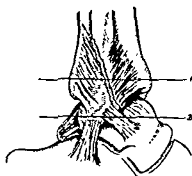


Fig. 608. "Mixed oblique" fracture of the fibula showing the ligamentous attachments to the fragments

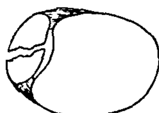


Fig. 609. Section of Fig. 608 at A showing line of fracture of the fibula between the anterior and posterior tibio-fibular ligaments.

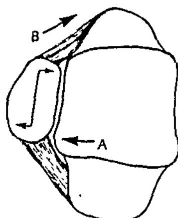


Fig. 610. Section of Fig. 608 at B showing the mechanism of fracture. The pressure of the talus at A and the pull of the posterior talo-fibular ligament at B, develop a "couple" acting on the lower end of the bone.

malleolus results in an adduction fracture. The shaft is freer to move anteriorly and posteriorly, and could be fractured by being bowed either forward or backwards. This could only occur with the syndesmosis acting as a fulcrum and pressure on the malleolus either anteriorly or posteriorly, and then only with difficulty. Owing to the posterior position of the fibular malleolus pressure can only be brought to bear on it anteriorly and this only becomes really effective when the fibula is displaced even further posteriorly by the rupture of the anterior tibio fibular ligament. Rotation then occurs around the posterior tibial tubercle, the fibula is bowed forwards and breaks around the junction of the lower and middle third, the so-called Dupuytren's fracture (Fig. 618).

The one mechanical force acting indirectly on the fibular shaft is thus external rotation of the foot, which through the pull of the posterior talofibular ligament, and pressure on the anterior margin

of the tibia builds up a torsional strain in the fibular malleolus (Figs. 608–610). The common result of this is that the ligaments hold and a first degree external rotation fracture (Fig. 631) occurs thus relieving the shaft of strain. Only when the anterior tibio-fibular ligament yields is strong torsion applied to the fibular shaft. The other force is that of bending, the fibula being either bowed forwards or medially, due to pressure on the inner or anterior aspect of the fibular malleolus. These are the only two forces which can act on the syndesmosis to produce diastasis and as the fibula fracture is the outcome of the degree of diastasis it must next be discussed.

TIBIO-FIBULAR DIASTASIS

Diastasis of the tibio-fibular syndesmosis results from either external rotation strain or abduction strain, the former being the more common cause. Let us consider the effects of external rotation first. Tension is built up in the anterior tibio-fibular ligament first as this is the tightest of the three ligaments of the syndesmosis. The ligament then yields by either tearing or avulsion the bone at one or other end. The fibula can now be further externally rotated and separates anteriorly from the tibia. Torsion strain develops in the shaft and the fibula fractures at its weakest spot, namely the neck of the fibula. This is Maisonneuve's fracture. It may be overlooked by concentrating on the ankle injury, and not examining the head of the fibula or the fact that there is an important ligamentous injury to the ankle not deduced from the fracture when it is seen.

If the force continues to act the antero-lateral capsule of the ankle is torn and the interrosseous ligament. The fibula is displaced further backward and pressure is brought to bear by the external rotation of the foot on its anterior margin. The posterior tibial tubercle or the posterior tibio-fibular ligament acts as a fulcrum, and the fibula is bowed forward as well as externally rotated, and fractures at the junction of its lower and middle third. The fracture is spiral in form though often comminuted due to flexion. This is Dupuytren's fracture (Fig. 618).

The force has usually exhausted itself by this time, but should it still continue the posterior tibial tubercle may be fractured or avulsed, and posterior dislocation of the ankle occur.

Abduction force is developed by direct pressure of the talus against the inner aspect of the fibular malleolus. The anterior tibio-fibular ligament being tightest, feels the strain first, but the force is usually so great that all three ligaments are torn together or in rapid sequence, and the foot and lower end of the fibula widely abducted producing a flexion fracture high in the fibular shaft (Fig. 621).

the fibula are therefore a reflection of the ligamentous damage around the fibular malleolus, and it is as such that they must be considered, for soft tissue injury is equally important to bone injury. The guide to fibular fractures is diastasis, which must therefore be considered first.

The shaft of the fibula can be broken by bending it medially, laterally, anteriorly or posteriorly. If bent medially it presses against the tibia, and this prevents fracture unless the tibio-fibular syndesmosis yields, and this is the common method of rupture of the joint in abduction injuries. If bent laterally it is supported by the interosseous membrane, and the adduction force applied to the

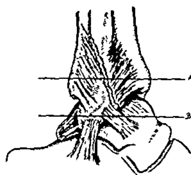


Fig. 608. "Mixed oblique" fracture of the fibula showing the ligamentous attachments to the fragments.

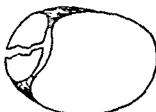


Fig. 609. Section of Fig. 608 at A showing line of fracture of the fibula between the anterior and posterior tibio-fibular ligaments.

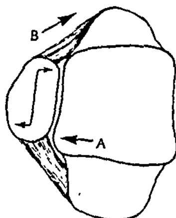


Fig. 610. Section of Fig. 608 at B showing the mechanism of fracture. The pressure of the talus at A and the pull of the posterior talo-fibular ligament at B, develop a "couple" acting on the lower end of the bone.

malleolus results in an adduction fracture. The shaft is freer to move anteriorly and posteriorly, and could be fractured by being bowed either forward or backwards. This could only occur with the syndesmosis acting as a fulcrum and pressure on the malleolus either anteriorly or posteriorly, and then only with difficulty. Owing to the posterior position of the fibular malleolus pressure can only be brought to bear on it anteriorly and this only becomes really effective when the fibula is displaced even further posteriorly by the rupture of the anterior tibio fibular ligament. Rotation then occurs around the posterior tibial tubercle, the fibula is bowed forwards and breaks around the junction of the lower and middle third, the so-called Dupuytren's fracture (Fig. 618).

The one mechanical force acting indirectly on the fibular shaft is thus external rotation of the foot, which through the pull of the posterior talofibular ligament, and pressure on the anterior margin

better under a general anaesthetic, though where the syndesmosis is very loose it may be appreciated without it. The malleolus is grasped between finger and thumb and its range of antero-posterior movement tested. Normally it is very slight, one millimetre each way.

Attempts have naturally been made to establish radiological criteria for the diagnosis of diastasis, but because of the varying depth of the tibial groove in which the fibula lies this has proved very difficult.

Diastasis is shown on the radiograph by increased space between the tibia and fibula, and for the correct determination of this it is important that the radiograph should show the bi-malleolar plane (Fig. 622) and that radiographs of both ankles should be available for comparison. This is necessary as the depth of the groove in

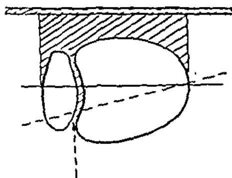


FIG. 612. The radiology of the tibio-fibular syndesmosis. If the groove is deep, the central ray cannot pass through uninterruptedly. Note the angle of 30° between the bi-malleolar axis and the angle of movement of the joint.

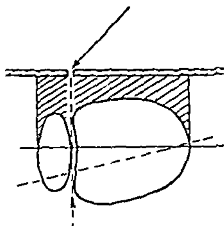


FIG. 613. When the tibial groove is *shallow*, a clear space can be seen. This may be seen in diastasis and mistaken for separation of the bones.

which the fibula lies varies. It has been stated that it is impossible for a gap to exist between the bones radiographically in the normal ankle, and that any appearance of gap is an indication of diastasis. This is emphatically not so. The only indication of diastasis is increased gap in comparison with the opposite side (Figs. 612, 613).

Factors suggesting diastasis may be noted in the ordinary radiograph. Thus the shadow of the anterior tubercle which normally overlies the fibula may barely appear to touch it. A more important point suggesting the condition is the increase in space between the medial malleolus and the medial side of the talus. This may, however, be deceptive and produced by external rotation alone.

Where there is a sprain fracture as indicated in the previous

It will thus be seen that external rotation produces a sequence of strains, each ligament of the syndesmosis being ruptured in turn from before back, while abduction tends to rupture the syndesmosis *in toto*. Diastasis may accordingly be divided up into stages.

First stage.	Rupture of the anterior tibio-fibular ligament.	Partial diastasis.
Second stage.	Rupture of the anterior tibio-fibular ligament and the interosseous ligament.	
Third stage.	Rupture of all three ligaments.	Complete diastasis.

Sprain fracture in association with diastasis. As a guide to the occurrence of diastasis it is important to remember that the portion of bone to which any ligament is attached may be avulsed instead of the ligament rupturing. The significance of such fragments must be recognised. They are sometimes called the "third fragment of Tilleau," after the man who first emphasised their significance, though they were recognised at the end of the eighteenth century. The fragments which may be separated are :—

1. The whole fibular groove, *i.e.*, both anterior and posterior tubercles joined by the bone lying between them. This permits a complete diastasis.

2. The anterior tubercle alone. This may indicate a partial or complete diastasis (Figs. 614, 618)

3. Rarely the fibula attachment of the anterior tibio-fibular ligament is avulsed.

4. The posterior tubercle. This may be avulsed, but is commonly split off by the pressure of the fibula on the back of the groove, when it occurs alone without displacement from kicks on the outer aspect of the fibular malleolus (Fig 614).

The diagnosis of diastasis. This may best be deduced from the type of fracture of the fibula, but there are rare cases, *e g.*, rupture of the anterior tibio-fibular ligament without fracture of the fibula in which it must be deduced on clinical grounds. The diagnosis is dependent on noting the bruising and pain over the anterior tibio-fibular ligament, and testing clinically the degree of movement at the syndesmosis by comparison with the opposite side (Fig. 611). This can only be done after the injection of a local anæsthetic, or



FIG. 611. Testing the mobility of the fibular malleolus clinically.

better under a general anæsthetic, though where the syndesmosis is very loose it may be appreciated without it. The malleolus is grasped between finger and thumb and its range of antero-posterior movement tested. Normally it is very slight, one millimetre each way.

Attempts have naturally been made to establish radiological criteria for the diagnosis of diastasis, but because of the varying depth of the tibial groove in which the fibula lies this has proved very difficult.

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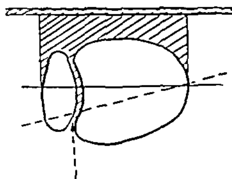


FIG 612. The radiology of the tibio-fibular syndesmosis. If the groove *is deep, the central ray cannot pass through uninterruptedly.* Note the angle of 30° between the bi-malleolar axis and the angle of movement of the joint.

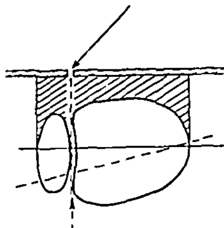


FIG 613. When the tibial groove is shallow, a clear space can be seen. *This may be seen in diastasis and mistaken for separation of the bones.*

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Where there is a sprain fracture as indicated in the previous

paragraphs the diagnosis is simplified, as this gives a clear indication of the ligament avulsed.

Fracture of the posterior tibial tubercle frequently accompanies a diastasis, or the attachments of the posterior tibio-fibular ligament may be torn, which may be indicated by the appearance later of the posterior tibial flake (see below). The mechanism of fracture is either one of avulsion, or the posterior tubercle is pushed off the tibia by the pressure of the fibula. It is possible to get a fissure fracture without displacement from a direct kick over the fibular malleolus. It is then of little moment and can be treated by early exercises and weight bearing as the stability of the ankle is not upset.

Where it results from the backward pressure of the fibula on the tibial groove the fibula is liable to yield above. The foot in external rotation and abduction presses on the anterior margin of the fibula which, without the support of the posterior lip of the gutter, rotates around the anterior tibio-fibular ligament, causing the fibula to bend



FIG. 614. Fractures of the anterior and posterior tubercles of the tibia gutter of the fibula—the third fragment.

anteriorly. Here it is not supported by the tibia and a flexion fracture often of the " butterfly " type results. Owing to the intact interosseous membrane and anterior tibio-fibular ligament displacement is small. The fracture is treated in the same manner as Dupuytren's fracture, from which it is distinguished by the shape of the fractured surfaces and the involvement of the posterior tibial tubercle.

Diastasis when complete is dramatic, but in itself is a comparatively harmless lesion, as it does not involve any weight-bearing surface in a fracture, and with adequate treatment the torn ligaments heal soundly. It is important, however, in paving the way for severe damage to soft tissues and for fracture of the fibula, and its treatment will be discussed with fractures of the ankle.

The posterior tibial flake. It is not uncommon to see in radiographs after old injuries, and appearing in radiographs a few weeks after recent injuries, a small flake of bone lying behind the tibial tubercle. It resembles in many ways the flake of bone seen lying at the attachment of the medial collateral ligament to the femoral condyle. It is smooth, dense, and separated from the bone by a

clear area. This clear area is occupied by some fibres of the posterior tibio-fibular ligament and the flake represents an ossification on the surface of this ligament. It may follow any severe injury to the ankle which results in a hæmatoma being formed in this region. It is of no significance, but should not be mistaken for a recent fracture.

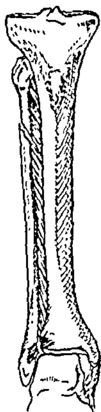


Fig. 615 Fracture of the fibula in the upper third by diastasis—Maisonneuve's fracture. Either the posterior tubercle (Fig 614) can fracture, or the anterior tibio-fibular ligament, as in this case, can rupture, allowing sufficient rotation for the fibula to fracture at its weakest spot. The first degree of diastasis.



Fig. 616. Maisonneuve's fracture—high fracture of the fibula accompanied by diastasis.

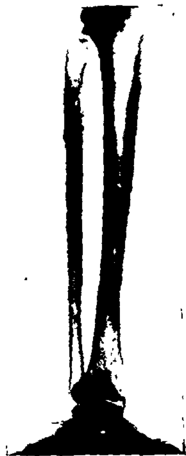


Fig. 617. High fracture of the fibula accompanied by fracture of the posterior tibial tubercle.

Fractures of the Fibula associated with Diastasis

1. Maisonneuve's fracture. This is a fracture which is commonly overlooked. Rupture of the anterior tibio-fibular ligament allows sufficient rotation strain to be imparted to the shaft of the fibula for it to fracture just below the head of the bone. The pressure is imparted to the lower end of the fibula by the anterior edge of the talus and by the pull behind of the posterior talo-fibular ligament.

The only symptoms may be local bruising over the anterior tibio-fibular ligament, which is very tender, and pain over the upper

end of the fibula, this may be slight and only elicited on pressure. The radiograph of the ankle in the normal antero-posterior plane is usually negative, and it requires either a film in the bi-malleolar plane or a film of the upper end of the fibula to determine the lesion. A very rare complication is the inclusion of the peroneal nerve in the upper fracture line with a peroneal palsy and foot drop.

TREATMENT. The principal disability arising from a failure to

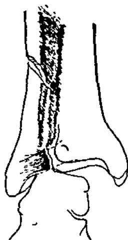


FIG. 618. Fracture of the fibula by diastasis, the posterior tibio-fibular ligament, shown by dotted lines, remaining intact. The second degree of diastasis. Note level of the fracture and that in the lateral view, the fracture line runs in the opposite oblique to that of the common "*mixed oblique*" fracture. "Dupuytren's Fracture."



FIG. 619. Dupuytren's fracture. Fracture

treat this lesion is a slight increased width in the tibio-fibular mortice and persistent pain over the anterior tibio-fibular ligament. To avoid this it is necessary to immobilise the ankle in a walking plaster for four weeks. A satisfactory skin-tight plaster can only be applied after the swelling has subsided, so that elevation and bandaging of the limb is a necessary preliminary for a few days. Rehabilitation after removal of the plaster is rapid and easy, and no disability should persist.

2. **Dupuytren's fracture.** Fracture of the fibula $2\frac{1}{2}$ inches above the syndesmosis with rupture of the anterior tibio-fibular ligament

and the interosseous membrane. The mechanism is one of external rotation combined with some abduction, so that pressure continues on the anterior end of the fibula, which is forced out and back. The rupture of the anterior tibio-fibular ligament is followed by a tearing of the interosseous membrane which allows the tibo-fibular syndesmosis to open up to the full extent permitted by the slack posterior tibio-fibular ligament, and this is followed by snapping of the fibula at the upper level of the tear in the interosseous membrane, 2½ inches above the malleolus. It is to be noted that unless the syndesmosis is damaged in some manner fracture of the fibula above it, except by direct violence, is impossible, as the fibula comes to lie against the tibia before its limit of elasticity is passed. It is also to be noted that the fracture line in such cases usually slopes in the opposite direction to the " mixed oblique " fracture, namely, from above and in front downwards and backwards.

TREATMENT. Owing to the intact posterior tibio-fibular ligament displacement is limited, and reduction of the diastasis is straightforward. The lesion is, however often accompanied by either rupture of the deltoid ligament or a transverse fracture of the medial malleolus with separation. The medial malleolus should under these circumstances be pegged back into position with a bone peg or a screw. Through the intact ligaments attaching it to the fibula it assists materially in maintaining the reduction of the syndesmosis. It is unnecessary to fix the fibula and tibia together by a screw in this type of case. The post-operative care and the care of the case which has been reduced manually is similar. Weight bearing must be delayed owing to the danger of the talus slipping over into eversion and pushing the fibula away. A short leg plaster is therefore applied as soon as swelling has subsided and activity on crutches permitted for the first six weeks. At the end of this time the leg is re-plastered and weight bearing permitted. The plaster is removed between the tenth and twelfth weeks. Satisfactory function should return to the joint, provided the damage on the medial side has not been too extensive. Some minor disability may persist for a time and it will be necessary to wear a crepe bandage for some weeks to control the swelling of the ankle.

Complete diastasis. This is produced by severe abduction violence, or by external rotation followed by abduction of the foot. All three attachments of the fibula to the tibia are torn and the anterior or posterior tubercle frequently accompanies them. Wide separation of the bones is permitted (Fig. 621) the talus sometimes riding up between them, when it may then be described as dislocated upwards between the two bones. The fracture of the fibula is usually in the middle third of the shaft and corresponds to the upper

end of the fibula, this may be slight and only elicited on pressure. The radiograph of the ankle in the normal antero-posterior plane is usually negative, and it requires either a film in the bi-malleolar plane or a film of the upper end of the fibula to determine the lesion. A very rare complication is the inclusion of the peroneal nerve in the upper fracture line with a peroneal palsy and foot drop.

Treatment. The principal disability arising from a failure to

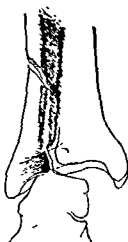


Fig. 618. Fracture of the fibula by diastasis, the posterior tibio-fibular ligament, shown by dotted lines, remaining intact. The second degree of diastasis. Note level of the fracture and that in the lateral view, the fracture line runs *in the opposite* oblique to that of the common "mixed oblique" fracture. "Dupuytren's Fracture."



Fig. 619. Dupuytren's fracture. Fracture of the lower third of the fibula together with an incomplete diastasis (rupture of the anterior tibio-fibular ligament).

treat this lesion is a slight increased width in the tibio-fibular mortice and persistent pain over the anterior tibio-fibular ligament. To avoid this it is necessary to immobilise the ankle in a walking plaster for four weeks. A satisfactory skin-tight plaster can only be applied after the swelling has subsided, so that elevation and bandaging of the limb is a necessary preliminary for a few days. Rehabilitation after removal of the plaster is rapid and easy, and no disability should persist.

2. Dupuytren's fracture. Fracture of the fibula $2\frac{1}{2}$ inches above the syndesmosis with rupture of the anterior tibio-fibular ligament

elevation of the limb, and replaster as soon as the swelling has subsided, usually results in a satisfactory reduction of the diastasis which should be checked by a bi-malleolar radiograph of both ankles. If reduction of the space between the two bones is unsatisfactory, it may sometimes be influenced during the first week by the application of a firm Esmarch's bandage around the ankle. The heavy pressure built up forces the fibula back into the tibial groove. The bandage should only be left on for a few minutes and the ankle then re-plastered.

Failure to reduce the fracture satisfactorily is uncommon and may be due to the interposition of soft tissue or a fragment of bone. Under these conditions operative reduction is necessary and the syndesmosis should be exposed by an anterior incision, cleared, and fixed by an oblique screw. This screw must be inserted at the correct level and not over-tightened. Over-tightening may result in tilting of the lower fragment, or of narrowing the mortice. The oblique screw is less liable to do this than the transverse. The screw should be removed at the end of treatment. Post-operative treatment demands freedom from weight bearing for six to eight weeks or longer if a posterior marginal fracture is associated. Consolidation is usually sound between twelve and fourteen weeks.

It is one of the advantages of operative fixation of the fibula that a plaster gutter splint may be made, and early exercises of the ankle carried out for the first six to eight weeks. By this time there is little danger of adhesions, and a walking plaster can be applied for a further six weeks in the secure knowledge that the ankle movements on its removal will be good.

Fractures of the fibular malleolus, and other lesions not associated with diastasis will be discussed with fractures of the ankle, where for completeness, some of the points made will necessarily be repeated. The principal fractures remaining to be discussed are

1. The first degree external rotation fracture and its complications namely second and third degree lesions.
2. The first degree abduction fractures and second and third degree lesions.
3. The first degree adduction fracture and second and third degree lesions.
4. Avulsion of the lower tip of the fibula.
5. Posterior dislocation of the fibula (without fracture).

Fatigue fractures of the Fibula. The area of maximal fibular strain corresponds to the upper level of the first degree external rotation fracture of the ankle, namely 1 to 1½ inches above the tibial plafond. Here similar changes to those described on page 545 in fatigue fracture of the tibia, or in March fracture may be seen. The *condition* is uncommon and occurs in

limit of the tearing of the interosseous membrane. The severe signs and symptoms present enable it to be diagnosed readily.

This fracture may be accompanied by fracture of the medial malleolus or a rupture of the deltoid, one or the other being necessary to allow the lateral displacement of the foot. Sometimes the posterior margin of the tibia accompanies the fibula instead of just the tubercle being involved, producing a third degree lesion (Fig. 647).

TREATMENT. This is essentially similar to that for second degree lesions (Dupuytren's fracture), but as the posterior tibio-fibular ligament is also involved reduction is not so easy or so stable. Reduction may

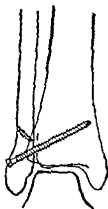


FIG 620. Single screw fixation for diastasis. Note the oblique insertion of the screw which does not tend to rotate the lower fragment of the fibula if not inserted at the correct level.

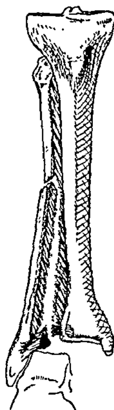


FIG. 621. Fracture of the fibula by complete diastasis. Note the separation of the anterior tubercle as "the third fragment."

be considerably assisted by operating on the associated fractures if these are displaced. Thus a medial malleolus should be pegged back and if the posterior margin is involved it should be accurately reduced. The lower end of the fibula is thus retained in position by its attached ligaments. Reduction when first seen is manipulative, and it is from a consideration of the control radiographs that a decision as to further treatment is made. Careful reduction and fixation of the associated fractures combined with

CHAPTER XXXII

FRACTURES AND FRACTURE DISLOCATIONS OF THE ANKLE

Surgical anatomy. The capsule of the ankle joint is attached to the tibial epiphysis, the e[illegible] To appreciate the more complicat[illegible] knowledge of the anatomy of the [illegible] can only mention the more important points here. The tibio-fibular mortice is much deeper on the outer side, corresponding to the lower position of the fibular malleolus, which lends lateral support to the ankle. This is compensated for medially by the strength of the deltoid ligament. Posteriorly the tibial articular surface is deeper than anteriorly, and this is increased by the lateral malleolar ligament. The upper surface of the talus is convex, with a sharp lateral margin, and a curved medial margin, and it is broader anteriorly than posteriorly, so that lateral movements at the ankle are impossible in the dorsiflexed foot, but possible in the plantar flexed, when the narrow posterior portion is engaged in the tibial mortice. These are the only movements occurring at the ankle joint, inversion and eversion of the heel take place at the sub-taloid (sub-astragaloid) joint, while inversion and eversion of the forefoot are usually combined with adduction and abduction and take place at the intertarsal and tarso-metatarsal joints.

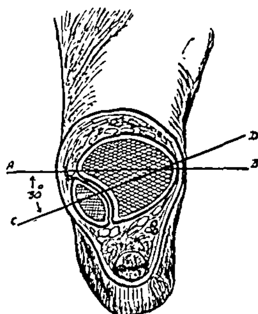


FIG. 622. Transverse section of the tibia and fibula immediately above the ankle joint. A–B, axis of movement of the ankle joint. C–D, malleolar axis. The angle of 30 degrees made by this with the axis of the ankle is shown, also the relationship of the anterior and posterior tuberosity of the tibia to the fibula in an A.P. radiograph (see Fig. 630).

In 4 per cent. of cases, however, the fibular collateral ligament is unusually lax, and on inversion of the foot the talus twists in the tibio-fibular mortice. This must be borne in mind in examination of ankles under inversion strain to determine the degree of ligamentous damage present.

The ankle joint depends on its stability on the strong bony mortice supported by the collateral ligaments of the ankle. The ankle joint is weakest anteriorly and posteriorly, and it is through these weak areas that dislocation of the talus most commonly occurs. As the grip of the mortice on the talus is only relaxed in plantar flexion, it follows that it is only in this position that complete dislocation of the talus can occur without fracture of the ankle. Incomplete dislocation of the talus is not uncommon, and its degree is the

adolescents subject to unusual and long-continued exercise, as in military training. Local aching and swelling are found with perhaps palpable thickening of the fibula, due to the sub-periosteal new bone formation. Natural recovery occurs in a few weeks with rest.

FURTHER READING

BONNIN, J. G. "Injuries to the Ankle," 1950. Wm. Heinemann Medical Books.

3. The interosseous membrane. This is ruptured in its lower portion in a few cases where the anterior ligament is torn. It can only be ruptured [illegible] the anterior and posterior ligaments are torn.

[illegible]

and that if the tibio-fibular joint is to be accurately seen the foot [illegible]

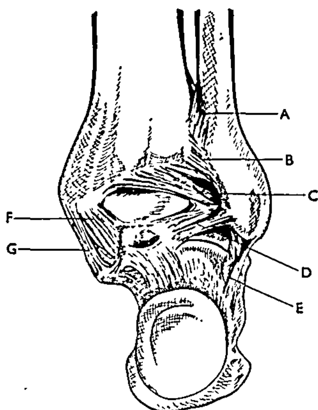


FIG. 624. The ligaments of the ankle from behind :—

A. [illegible]
B. [illegible]
C [illegible] continuation of the [illegible] the tibial surface for the talus.
D. Posterior talo-fibular ligament.
E. Calcaneo-fibular ligament.
F. Posterior talo-tibial ligament. } 2nd and 3rd parts of deltoid
G. Calcaneo-tibial band. } ligament.

turned inwards for 30 degrees so that the bi-malleolar axis is parallel with the plate.

It is also important to note that the anterior tubercle of the tibia is always the more prominent tubercle in the radiograph, though it gives the impression on casual inspection of lying behind the fibula (Fig. 627).

Introductory. The lesions occurring around the ankle joint are simple in origin though complex in variety. An understanding of the mechanism makes the appreciation of the large variety of lesions met with fairly easy, and is well worth the trouble spent. It will be found that the causative forces can be resolved into four main

really important feature in lesions in the ankle region, as it is the true measure of the amount of damage done.

The range of movement of the ankle joint is surprisingly limited. Dorsiflexion and plantar flexion of the foot take place through an arc of 40 degrees, the apparently greater range being due to additional movement at the tarsal joints. Of particular importance in the study of the lesions of the ankle is the tibio-fibular syndesmosis. This joint imparts an elasticity to the mortice which would otherwise be lacking. If the tibio-fibular mortice is firmly closed by a screw passing across it, dorsiflexion of the foot will be prevented. There are three chief ligaments responsible for maintaining the apposition of the fibula, and they are important as on the sequence of their rupture, and



FIG. 623. The ligaments of the tibio-fibular syndesmosis seen from the lateral aspect :—

A. Anterior tibio-fibular ligament.
B. Posterior tibio-fibular ligament.
C. Anterior talo-fibular ligament.
D. Posterior talo-fibular ligament.
E Calcaneo-fibular ligament.

on the ligament ruptured, the many variations of fracture of the fibula depend. The ligaments are :—

1. The anterior tibio-fibular. This is a short and strong ligament which runs from the anterior tubercle of the tibia to the anterior aspect of the fibula. It permits the two millimetre upward and backward movement present.

2. The posterior tibio-fibular ligament. This is a longer ligament spreading out on the back of the posterior tibial tubercle, and which is slacker than the anterior. Part of the ligament deepens the mortice, and is known as the lateral malleolar ligament. Division of the anterior ligament allows the tibia to be separated from the fibula for one centimetre, the condition often present in diastasis.

Summary of the Fractures around the Ankle

Force	*Fracture*		*Stability of ankle*
External rotation 60% of cases.	First degree .	Oblique fracture of malleolus.	Stable to all strains but external rotation.
	Second degree	The same fracture with fracture of the medial malleolus.	Unable to resist external rotation or lateral pressure.
	Third degree.	The same fractures with a posterior marginal fracture.	Unstable to all strains.
Abduction . 15% of cases.	First degree .	Fracture of the fibular malleolus above the plafond.	Stable to all strains but abduction.
	Second degree	The same fracture with fracture of the medial malleolus.	Unable to resist abduction and lateral pressure.
	Third degree.	The same fractures with a posterior marginal fracture.	Unstable to all strains.
Adduction . 18% of cases.	First degree .	Fracture of the medial malleolus (vertical)	Stable to all strains but adduction.
	Second degree	The same fracture with fracture of the fibular malleolus.	Unstable to adduction or medial pressure.
	Third degree.	The same fractures with posterior marginal fracture.	Unstable to all strains.
Compression 7% of cases.	First degree .	Anterior marginal fracture. Posterior marginal fracture.	All unstable to weight bearing.
	Second degree	Fracture of a malleolus and a marginal fracture.	
	Third degree.	Comminuted fractures and T and Y shaped fractures.	

Ligament Injuries

As certain injuries to ligaments produce the same degree of instability as some equivalent fractures it follows that a brief discussion of ligamentous injuries is an essential preliminary to discussion of fractures of the ankle as a whole. The reader is referred again to the preliminary discussion on ligamentous injury on p. 1.

The serious consequences of ankle injury are dependent, firstly, on damage to the weight-bearing portion of the ankle, and, secondly, on ligamentous injury. It is extremely important to bear in mind

groups, though most often occurring in combination. These are: (1) External rotation, (2) Abduction, (3) Adduction, (4) Compression. The lesions following the application of these forces follow a pattern due to the sequence of ligamentous rupture and the yielding of the malleoli.

We have discussed in the previous chapter the production of diastasis, or separation at the tibio-fibular syndesmosis by the forces of external rotation and abduction. It follows logically that the fractures produced by external rotation and abduction may be complicated by diastasis, and so their variety is increased. Fractures of the ankle may be grouped according to the number of malleoli fractured, and for this purpose the posterior tibial margin may be regarded as a third malleolus. We can have un-malleolar, bi-malleolar and tri-malleolar fractures. In practice it is best to group the fractures under the dominant causative violence, as this enables the sequence of events to be grasped and encourages the consideration of soft tissue injuries as equivalent to bone injury in the situations where the mechanism is the same and the only difference is the level of rupture—for example, rupture of the deltoid ligament and separation of the medial malleolus

Because of the configuration of the foot, external rotation causes definite and almost invariably similar stress which produces a series of readily recognisable changes. With abduction and adduction the stresses are not so uniformly applied. Thus in abduction the foot may be rotated around its longitudinal axis, producing tension in the deltoid ligament, or the foot may be pushed like a drawer directly sideways against the inner aspect of the fibular malleolus The action of both forces and combinations of both forces are included in the term "abduction." The same considerations apply to adduction strain. It is obvious that whichever element is the dominant force will affect the physical shape of the fracture Sub-varieties of abduction and adduction fractures are therefore often met with.

Note.—Fractures of the ankle are commonly lumped together under the name of "Pott's fracture" or "Dupytren's fracture." Unfortunately both [illegible]

[illegible] accompanying it. The commonest [illegible] of the ankle which both Pott and Dupytren thought they were describing is the first degree external rotation fracture, first accurately described by Maisonneuve in 1840. His name, which should be perpetuated in the name of this fracture, is attached to the rarer torsional fracture of the fibula just below the head, for which a preliminary tibio-fibular diastasis is necessary.

The term "mixed oblique" fracture for this first degree external rotation lesion has been coined by Destot. It is called "mixed" because the fibula is involved both above and below the tibio-fibular syndesmosis.

by radiography, an attempt to assess the severity of the lesion should be made. If from the physical signs it is considered trivial simple measures, such as strapping or bandaging it, may be adopted. If it has raised suspicion of fracture it is more likely to be a partial or complete ligamentous rupture, and steps should be taken to prove the exact degree of damage by assessing the degree of rotation permitted to the talus (Figs. 625, 626).

This may be done clinically under local anæsthesia, but as this does not abolish all muscle spasm general anæsthesia is to be preferred. The mobility of the talus or of the fibular malleolus is tested clinically by putting the affected ligament on the stretch, and the results are best recorded radiologically (strain radiography). It must be remembered that 4 per cent. of people have slight relaxa-



FIGS. 625 and 626. The hypermobile an[illegible] ankles shows that there is relaxation [illegible] on the left side, permitting a slight tilt [illegible] has been a rupture of the calcaneo fibular portion of the ligament permitting further tilt.

tion of the fibular collateral ligament, and this permits the talus to angle up to 10°. Comparable films of the opposite ankle are therefore needed in accurate work.

The strains usually employed are :—

1. Adduction strain. Rupture of the fibular collateral ligament.
2. Abduction strain. Rupture of the deltoid ligament.
3. External rotation strain. Rupture of the anterior tibio-fibular ligament and diastasis.
4. Plantar flexion. Rupture of the anterior fasiculi of both collateral ligaments, and diastasis.

The Diagnosis and Radiology of Fractures of the Ankle

DIAGNOSIS. Owing to the subcutaneous nature of the bones, and the comparative simplicity of the gross movements at the ankle, lesions of the bones can usually be diagnosed with accuracy by

the fact that ligamentous injury may occur without bone damage. In any case in which the degree of bruising is disproportionate to the radiological evidence of damage, ligamentous lesions must be excluded. The ligaments involved may be the deltoid ligament, the fibular collateral ligament, divisible into three parts :—

The anterior talo-fibular ligament ;
the calcaneo-fibular ligament ;
the posterior talo-fibular ligament ;

and the ligaments of the syndesmosis :—

The anterior tibio-fibular ligament ;
the interosseous ligament ;
the posterior talo-fibular ligament.

Rupture of the syndesmosis in part or *in toto* constitutes diastasis and has already been discussed (p. 569).

Rupture of the collateral ligaments occurs by inversion or eversion and may be indicated by the avulsion of the bone to which the ligaments are attached. *The deltoid ligament* is firm and united and is rarely ruptured, and possesses sufficient rigidity to retain itself in place. Open repair is therefore seldom required.

The fibular collateral ligament has three recognisable portions and may rupture in part or *in toto*. Rupture of the anterior talo-fibular ligament occurs in the more severe external rotation injuries, and it can be best regarded as part of the anterior capsule of the joint and does not require special repair unless exposed for some other reason.

Rupture of the calcaneo-fibular portion is common and, when combined with wide separation of the talus from the malleolus, serious, as the ligament frequently gets caught up in soft tissues and cannot unite, leaving a permanently unstable ankle. Open repair of the ligament is thus often necessary.

The posterior talo-fibular ligament is so strong that it is seldom torn , indeed, the talus and the fibular malleolus have been described as the Siamese twins of the ankle. Even in the so-called complete rupture of the fibular collateral ligament, in which wide separation of the talus and the tibial plafond are possible on the lateral side (Fig. 627), the ligament remains largely intact, and the injury is due to rupture of the calcaneo-fibular ligament and wide capsular tearing involving, of course, the anterior talo-fibular ligament.

THE DIAGNOSIS OF LIGAMENT INJURIES AROUND THE ANKLE

This is based on the history of the injury, local bruising and tenderness, pain on stretching the affected ligament, and where muscle spasm is not too pronounced the impression of relaxation of the ligament. Bruising appearing around a malleolus should always raise suspicion of soft tissue injury and, having ruled out bony injury

includes elevation of the leg and fixation of the foot till accurate investigation is possible. Routine examination includes :—

1. *History.* The accurate details of the accident shed much light on the probable fracture, *if they can be obtained.*

2. *Inspection.* Deformity is usually present in any serious lesion, but bruising may be extensive in the absence of severe injury. Abrasions *should be noted, particularly as regards their site.*

3. *Palpation.* This may reveal bony irregularities, crepitus, and particularly areas of deep tenderness.

4. *Movements.* In sprain upward pressure on the sole is usually painless, while in fracture it is usually painful. Inversion and eversion will produce pain over the fractured malleoli. Lateral movement of the ankle joint may be detected. The examination for the detection of increased fibular mobility has been previously described (Fig. 611).

RADIOLOGY. The relation of the malleoli to the angle of movement of the ankle joint (Fig. 622) is important in radiology, as views of the joint when displaced or taken with odd degrees of rotation of the limb may be very confusing. A good antero-posterior film, *i.e.*, with the foot vertical, corresponds to the axis of movement of the joint. This will often give all the information required, but a film with the foot internally rotated through 30°, *i.e.*, in the bi-malleolar axis, shows up the malleoli much better and is essential in the accurate diagnosis of diastasis and of widening of the space between the talus and the medial malleolus (the medial clear space).

The routine examination is usually a true antero-posterior and true lateral radiograph of the joint. It is possible in such films to overlook a " mixed " oblique fracture of the fibula with no displacement if the fibula is entirely hidden by the tibia. This indicates an oblique film, the fibula lying just behind the tibial shadow in the true lateral radiograph (Fig. 617).

Supplementary radiological examinations which may be helpful in difficult cases are :—

(*a*) The bi-malleolar film, which shows up the syndesmosis, giving evidence of minor degrees of diastasis.

(*b*) Radiographs under strain, previously mentioned.

(*c*) A radiograph of the opposite ankle in *inversion,* to exclude the hypermobile ankle, necessary in cases which are clinically hypermobile.

(*d*) A radiograph of the upper end of the fibula to exclude fracture of the neck associated with rupture of the anterior tibio-fibular ligament (Maisonneuve's fracture) (Fig. 615).



FIG. 627. Severe sprain of the ankle. Rupture of the fibular collateral ligament without fracture. The dislocation of the talus is only seen if the ankle is X-rayed in strong inversion. The severity of the injury would consequently not be appreciated in the usual X-ray.



FIG 628 Fracture of the lower end of the tibia involving the ankle joint due to direct violence.



FIG 629. The same case after reduction by manipulation and fixation in plaster.

clinical examination unless the case is seen late when swelling, which is often gross, renders any examination difficult. This swelling is due to venous rupture accompanied by œdema from the dependency of the leg, and the preliminary treatment of all cases

in the mortice of the tibio-fibular syndesmosis. Mechanical principles determine that the strain will fall on the anterior margin of the fibular malleolus to a maximal extent. This push on the anterior margin of the fibula is supplemented by the pull on the posterior margin or the posterior talo-fibular ligament. These combined forces produce a torsion strain on the lower end of the fibula, which is attached most firmly to the tibia by the anterior tibio-fibular ligament. If this holds, the fibula snaps in a characteristic manner. A torsional fracture is produced (Fig. 632), which is obviously spiral, or else oblique, and runs from the posterior surface of the fibula downwards and forwards to end on the anterior aspect of the lateral malleolus just below the level of the lower tibial articular surface. This course leaves the anterior tibio-fibular ligament intact, which unites the sharp end of the proximal fragment to the tibia. The fracture line thus runs obliquely between the anterior and posterior tibio-fibular ligaments, being extra capsular above and intracapsular below (hence the term Mixed Oblique fracture). It will be noted that the talus remains attached to the lower end of the fibula and that this is attached to the tibia by the posterior tibio-fibular ligament. This allows a small range of movement depending on the damage to surrounding soft tissues, and it is obvious that if the posterior tibio-fibular ligament was ruptured the condition would be similar to that seen in a diastasis.



FIG. 632. First degree external rotation fracture. This fracture is typical, but differs from the more commonly seen lesion in that the fracture line is unusually oblique, and there is more separation of the fractured surfaces. The A.P. film shows no *diastasis* and no displacement. (Compare with Fig. 631.)

The degree of damage done depends on whether the force ceases to act after the fibula has snapped. We may thus get :—

1. Subperiosteal spiral fracture with no displacement.
2. A fracture with moderate displacement (Fig. 632).
3. A fracture in which there has been marked displacement

Injuries of the Ankle

The multiplicity of the lesions encountered in injuries to the ankle are composed of the following elements :—

1. Injuries to the ligaments.
2. Injuries to the malleoli.
3. Fractures of the posterior margin of the tibia (the "third malleolus").
4. Diastasis of the tibio-fibular syndesmosis. This is a special variety of ligamentous injury, occurring in external rotation and abduction only, and so only complicating fractures due to this particular type of violence.
5. Dislocation of the ankle joint.
6. Fracture of the fibular shaft (Chapter XXXI).
7. Injury to the talo-navicular joint and the subtaloid joint in dislocations of the talus (p. 615).

In the previous discussion of fibular fractures and diastasis (p. 567) the sequence of injury when external force is applied to the fibula and the anterior tibio-fibular ligament ruptures has been described. We must now consider the injuries which result when the ligament does not tear.

Fractures by External Rotation Force

First degree external rotation injury. The conversion of the foot into a rigid lever by external rotation results in a twisting of the talus

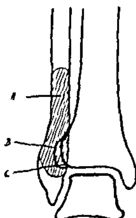


Fig. 630. A.P. diagram of a first degree external rotation fracture ("mixed oblique") of the fibula.
A. Shading indicating plane of fracture.
B. Shadow of anterior tuberosity.
C. Shadow of posterior tuberosity.

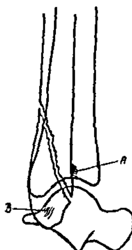


Fig. 631. Lateral view of a first degree external rotation fracture.
A Attachment of anterior tibio-fibular ligament (sometimes pulled out forming Tilleaux's third fragment).
B. The strong posterior talo-fibular ligament.

probably spontaneously reduced, but indicated by the signs of damage to the anterior fibres of the deltoid on the opposite side of the ankle (Fig. 633).

Treatment. The displacement of the *fragments in this first* degree lesion is, as a rule, minimal, indicating that the periosteal sheath of the fibula is probably intact, and the mechanics of the ankle will be little disturbed. The weight-bearing capability of the joint is undiminished, and consequently the fracture can be treated in a number of cases by a supporting bandage, it being sufficient to avoid further external rotational strain.

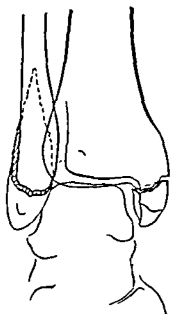


FIG 637. Second degree external rotation fracture of the ankle—A.P. view.

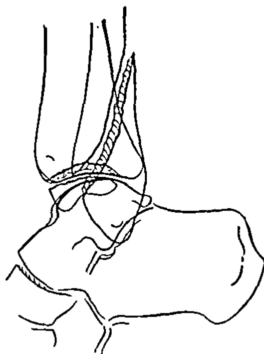


FIG. 638. Lateral view of same case. Note that the oblique fracture of the fibula is partly intra-articular, partly extra-articular.

LOCAL ANÆSTHESIA. This is primarily directed to the relief of pain, and satisfactory results will be obtained by the immediate injection of the fracture line with local anæsthetic, bandaging, and the early use of the limb. The pain of the injury having been relieved by local anæsthesia, the next essential is the prevention of swelling by firm bandaging of the ankle over cotton wool, and elevation of the limb. Immediate strapping with elastoplast is often painful as it does not expand sufficiently to accommodate the amount of swelling which may occur. The most essential part of the treatment is the encouragement of the patient to exercise the ankle after the pain has been abolished. Without this the value of the injection is problematical. Early radiant heat and massage should



Fig. 633. First degree external rotation fracture of the ankle, with lateral displacement.



Fig. 634. First degree adduction fracture.



Fig. 635. Second degree external rotation



Fig. 636. Same case as in previous figure after reduction.

At the end of this period some rehabilitation will be required and a crepe bandage will be necessary to control the œdema around the ankle. The use of an Unna's paste stocking makes massage impossible, though quite satisfactory in the younger case.

The prognosis in this type of case is excellent. Many mild cases will be walking well at the end of the first week. In the more serious group six weeks may elapse before recovery takes place completely. There should be no persistent disability.

Second degree external rotation injury. A. With rupture of the deltoid (tibial collateral) ligament. B. Associated with fracture of the medial malleolus.

In these cases the deforming force has continued to act after the torsion fracture of the fibula has occurred, and the displacement of the talus moving with the lower fibula fragment puts strain on the deltoid ligament, which ruptures or more commonly fractures the medial malleolus by traction leaving a spiral fracture line (Fig. 666).

Further displacement may result in the rupture of the posterior tibio-fibular ligament (Fig. 640) and a partial diastasis, which permits further outward displacement. With this degree of deformity and displacement of the talus it is obvious that the lateral stability of the ankle is destroyed, though the weight-bearing surfaces are still intact. The fracture must accordingly be treated more carefully to obtain a perfect result, and to avoid redisplacement from too early weight bearing, or too loose a plaster.

Treatment. Difficulty is again encountered from swelling which often necessitates several plasters before a firm close-fitting walking plaster can be applied. When first seen the fracture is readily enough reduced by manipulation, which on account of the intact talo-fibular ligament, and the small overhanging fragment of the medial malleolus, cannot be over-reduced by strong medial pressure applied to the outside of the foot, with counter-pressure by the hand on the medial aspect of the tibia. Care must be taken that the force applied moves the whole talus across, and does not merely invert the ankle. A plaster retaining slab is then applied to encircle the foot and leg for two-thirds of its circumference, holding the fracture reduced, and the foot in dorsiflexion and unrotated. This is held in position with a gauze bandage, and the controlling manipulation continued till the plaster has set. The foot is then elevated on a Braun's splint, and control radiographs taken. Should the position be unsatisfactory the ankle is remanipulated. Once satisfactory reduction is obtained, the leg is carefully watched, and, if necessary replastered, till swelling has subsided sufficiently for a close-fitting skin-tight walking plaster to be applied.

be given, and if the pain is not completely relieved a further injection should be given (10–20 ml. 1 or 2 per cent. novocaine). According to the amount of pain, the degree of swelling present, and the *weight, age, and ability of the patient*, a decision is made at the end of a few days as to when weight bearing in a boot can be commenced.

Alternative lines of treatment are a light plaster walking cast or use of an Unna's paste stocking after swelling has subsided. Both



Fig. 639. First degree external rotation fracture of the fibula accompanied by rupture of the attachment of the deltoid ligament—the equivalent of a second degree injury. Note the ligament separates at its periosteal attachment.



Fig. 640. Third degree external rotation fracture. A mixed oblique fracture of the fibula complicated by rupture of the deltoid and displacement of the talus. There is a diastasis present due to rupture of the anterior and posterior tibio-fibular ligaments.

these methods fail to get rid of the œdema and swelling so rapidly as novocaine injection and early exercises

Where the displacement has been marked as indicated by swelling, hæmorrhage, and possibly persistence of deformity in the radiograph, the ankle is not stable and is unsuitable for early weight bearing and exercises. An injection of novocaine can be given to reduce pain and enable massage to be given, *but the ankle will need support* in a posterior gutter splint, and as soon as swelling has subsided should be put in a short walking plaster for three weeks.

the cylindrical upper surface of the talus on the curved lower surface of the tibia. The fracture line runs vertically from the ankle joint to the posterior surface of the tibia, and a variable area of the articular surface may be involved. The lower fibular fragment invariably moves with the detached tibial fragment owing to the strength of the posterior tibio-fibular ligament, and the talus also moves backwards with the fibula because of the unbroken talo-fibular ligament (Fig. 648). In 25 per cent. of cases the fracture is present without displacement, consequently it is considered that displacement when present is due to the continuation of the injuring force.

Posterior marginal fracture. The posterior marginal fracture which characterises a third degree lesion, and allows backward and upward displacement of the talus, has to be carefully distinguished from fractures of the posterior tubercle of the tibia. A much smaller fragment of tibia is involved in this case corresponding to the posterior wall of the groove in which the fibula lies and the attachment of the posterior tibio-fibular ligament (Fig. 578). It is a much less serious lesion, as the articular surface is barely involved, and the shallow curve of the lower surface of the tibia remains intact.



Fig. 643. Appearance of the ankle in third degree lesions with posterior dislocation of the talus—third degree external rotation fracture.

That posterior marginal fractures are due to a combination of compression and rotation of the talus under pressure can be seen from the fact that they are most commonly associated with external rotation fractures and seldom with abduction fractures, while with adduction fractures they are extremely rare.

Treatment. The most important feature of this lesion is the destruction of the weight-bearing ability of the ankle, which remains intact in first and second degree lesions. The degree of interference with weight bearing will depend on the area of posterior articular surface detached, so that the seriousness of the condition is determined by the position in which the vertical fracture line enters the joint. If the fracture chips off only a small area from the posterior aspect of the joint, leaving the greater part of the curve of the lower articular surface of the tibia intact, then the interference with weight bearing is minimal (Fig. 579). If, on the other hand, the fracture line enters the joint at the summit of this curve, then the stability of the joint will be completely lost, and the *fracture line*

This is usually about the end of the second week. After the patient has walked in the plaster cast for a few days a control radiograph is taken through the plaster to see if redisplacement has occurred. The tendency most frequently seen is for the talus to become everted, so that some inversion of the heel in applying the plaster is no disadvantage, but the foot must be at right angles to the leg, and unrotated. Any tendency to redisplace in the plaster demands further rest, reduction and plaster. With injuries of this severity the plaster must be worn for some six to eight weeks from the date of the accident, and its removal will need to be followed by an elastic stocking, elastoplast or Unna's paste stocking for two to three weeks, during which time exercises are encouraged. At the end of this time free full movement of the ankle should be possible. After the removal of the plaster it is an advantage to give the patient a valgus insole to wear for a few months till the normal muscle tone of the leg has returned.

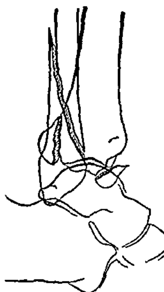


FIG. 641. Third degree external rotation fracture—long oblique fracture of fibula. Note oblique and involvement of the anterior surface of the tibia in the fracture of the medial malleolus, characteristic external rotation fracture of this process. (Compare with the displaced lesion in Fig. 648.)



FIG. 642. Reduction of a third degree ankle injury, original sketch of Thomas himself at work.

Third degree external rotation injury. The continuation of the force separates the posterior aspect of the lower tibial articular surface (Trethowan's third malleolus). This lesion is occasionally seen alone (Fig. 672) when there is no displacement of the foot backwards, and is then due to compression. In the third degree rotation fracture the lesion is due to a combination of compression injury, and a backward resultant force developed by the rotation of

useful when working single-handed and when no apparatus is available. The patient lies with the injured limb over the end of the table. A sling is tied over the anterior aspect of the tibia, consisting of a strong calico bandage of a length convenient to be held under the foot. A second similar but shorter sling is now passed under the heel and over the surgeon's neck, so that on straightening his back he can exert pressure against the heel, the counter-traction being applied by the sling over the tibia (Fig. 644). If a stockinette sling is placed over the foot and left long the patient or an assistant can readily maintain dorsiflexion by traction upon it.

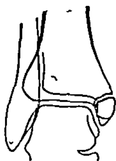


FIG 645. First degree abduction fracture of the medial malleolus. Note transverse line of fracture Compare with adduction and external rotation fractures of the medial malleolus.

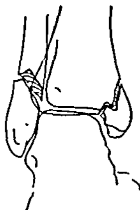


FIG. 646. The more common variety of second degree abduction fracture. (One variety of bimalleolar fracture.)

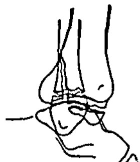


FIG. 647. A third degree abduction fracture lateral radiograph.

The surgeon's hands are thus left free to control the lateral displacement. A plaster is applied over the bands which are cut after it has set.

SKELETAL TRACTION. By inserting a wire in the calcaneus and placing the limb under traction on a Bohler frame the upward displacement of the talus can be controlled. The continuous distraction leaves the hands free for controlling the lateral displacements and maintains dorsiflexion. It is convenient to apply the plaster over the Kirschner wire, which is later withdrawn. In fresh cases the plaster is split down at once, or a posterior plaster slab may be applied followed by a long U-shaped slab on the sides of the limb to control lateral movements. This leaves an unplastered area for expansion. The Kirschner wire is left in position and a weight of 7 to 10 lbs. attached to it. This weight serves to separate the joint surfaces. The pin aids in retention and is convenient if

will be in a position where it is subject to maximum pressure in weight bearing, and so will be more likely to give rise to a later traumatic arthritis

Accuracy of reduction of this fragment is therefore very important, and in certain cases will justify the opening up of the fracture and pegging the fragment in place. In 25 per cent. of cases there is



FIG. 644. The manual method (Robert Jones') of reduction of a third degree fracture of the ankle Under local anæsthesia, the patient is able to maintain his own dorsiflexion, by pulling on the stockinette covering his foot By straightening the back, the dorsal dislocation is reduced, and kept reduced, while the two hands are left free for plastering and correcting lateral deformity. The bandages are cut away after the plaster has set.

no displacement to reduce, and it suffices to treat these as second degree lesions, but weight bearing must be deferred in accordance with the degree of destruction of joint stability.

In the cases in which a large fragment is displaced (Fig. 654), one of the following methods is adopted.

1. Reduction and plaster by Robert Jones' method.
2. Reduction and plaster under skeletal traction.
3. Open operation.

ROBERT JONES' METHOD. This is a simple and effective method

control at operation may be used conveniently. It is possible to replace the fragment through a posteriomedial incision where more care must be used on account of the posterior tibial vessels and nerves, and this approach may be conveniently used when it is necessary to fix the medial malleolus at the same time. The after-treatment is that of fractures reduced by manipulation.

Prognosis. This is governed by the degree of ligamentous damage, the age of the patient, and the size of the displaced posterior fragment, together with its response to attempts at reposition. If the fracture line runs high across the joint it is inevitable that there will be come dysfunction and the later development of traumatic arthritis.

External Rotation Fractures with Diastasis

The mechanism of diastasis has been discussed on p. 569. As the result of the strain placed on the syndesmosis the ligaments may tear in sequence (anterior, tibio-fibular, interrosseous and posterior tibio-fibular) and the tearing may be interrupted at any stage if the force ceases to act. Accordingly we may get the following fractures :

Rupture of the anterior tibio-fibular ligament :

High fracture of the fibular neck (Maisonneuve's fracture).

Rupture of the anterior tibio-fibular ligament and the interrosseous ligament :

Fracture of the fibular at the junction of the lower and middle third (Dupuytren's fracture). The posterior tibial tubercle may be damaged in association with this injury.

Complete diastasis :

High bending fracture of the fibular shaft.

The treatment of these fractures corresponds to the treatment of the first, second and third degree fractures without diastasis, the rupture of the ligaments making little difference to the end result, though the ankle is more unstable, and the reduction must be watched for a recurrence of the deformity, and replastered as swelling subsides, and retained in plaster a little longer.

Operative treatment. Direct interference to repair the diastasis is very seldom required. It may be necessary when .—

1 The fibular malleolus cannot be reduced.

2. Late cases in which there is fibrous thickening between the tibia and fibula.

3. The rare case in which there is a fragment of bone caught between the two bones.

If perfect reduction is not achieved by manipulation, the easiest and most useful way to obtain this is operative reduction and fixation of the medial malleolus (see p. 606).

further manipulation or plaster is needed. It is removed when the walking plaster is applied. This usually cannot be done till a period of four to five weeks has elapsed, if the stability of the joint is destroyed, though there is no objection to the patient getting about



FIG 648 Third degree external rotation fracture. Note the posterior displacement of the talus to which the fibula has remained attached The fibula shows a rotational fracture with a small triangle of bone separated. The medial malleolus is intact, indicating rupture of the deltoid ligament. Tibio-fibular *diastasis* has of course occurred.

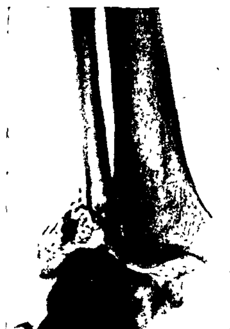


FIG. 649. Second degree abduction fracture of the ankle.

on crutches The usual precautions with regard to swelling and œdema are taken with redoubled care. A walking plaster will need to be worn a further four to five weeks, making a total period of disability in the worst case of twelve weeks, followed by a period of re-education in which the limb is first put in strapping for three weeks and then freely exercised without the strapping.

OPERATIVE REDUCTION. It is usual for manipulative methods to fail, and in a number of cases it will be necessary to operate to obtain satisfactory reposition of the posterior fragment. A posterior approach is used and the fragment screwed into place. Complete visualisation of the fracture may be *difficult*, but if the upper margin can be seen and replaced the screw will close the lower fracture line in the joint. Radiological



Fig. 650. A.P. radiograph of a first degree abduction fracture of the ankle. Note the almost transverse line of fracture.



Fig. 651. Lateral view of same case. Note that the displacement which appears minimal in the A.P. view is marked in this view.

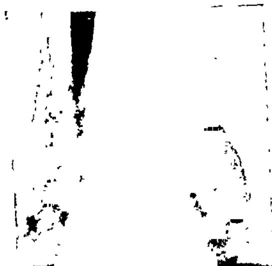


Fig. 652. Same case fixed with a single screw.

after-treatment is that of the corresponding external rotation lesion.

Abduction Fractures with Diastasis

The lateral pressure on the fibular malleolus tends to rupture the syndesmosis completely, producing wide lateral dislocation at the ankle, the talus sometimes coming to rest between the tibia and fibula. There is a high fracture of the fibular shaft. The injury is

External Rotation Fractures with Dislocation

Such fractures are third degree fractures, and the treatment is the same. If the dislocation is due to a posterior marginal fracture, either the posterior overhang of the tibia is sufficient for the reduction to be stable, or the reduction is unstable, in which case open operation and screwing the third malleolus back in position is necessary. This is done through a posterior approach, and it is often an advantage to fix the fracture of the fibula with a screw as a preliminary to reduction of the posterior marginal fracture, the under-surface of which cannot be completely visualised without risk of rendering the detached fragment avascular.

FRACTURES BY ABDUCTION FORCE

First degree abduction fracture. Fracture of the medial malleolus only. (Rarely rupture of the deltoid ligament.)

Second degree. Fracture of the medial malleolus or tear of the deltoid with fracture of the fibula below the tibio-fibular syndesmosis (bi-malleolar fracture) (Fig. 649).

Third degree. Any second degree lesion plus fracture of the posterior margin of the tibia.

The mechanism of abduction fractures is straightforward, and it has only to be remembered that this movement may be combined with external rotation, producing a combined lesion. Strain by abduction is first imposed on the deltoid ligament, which may yield, but more commonly tears away the medial malleolus producing a transverse fracture line. The more external rotation is combined with abduction the more oblique the fracture line. This corresponds to the first degree lesion, and the torn deltoid may be overlooked if in suspicious cases the foot is not X-rayed in inversion.

When either of these lesions have occurred the strain now falls on the inner aspect of the fibular malleolus, and the resultant fracture will depend on whether the tibio-fibular syndesmosis gives way. If it yields then the fibula fractures by flexion above the joint level If it remains intact then the fibula snaps off below the joint level, producing a bi-malleolar fracture. The lesion associated with diastasis and flexion fracture of the fibula above the joint is that most nearly akin to the lesion described by Pott.

In the third degree lesion there is an associated fracture of the posterior aspect of the tibia due to compression.

Treatment. The treatment runs parallel to that of the corresponding external rotation lesions The displacement being outward is corrected by forcing the foot medially on the fixed tibia. Care must be taken that the foot is moved across, and not merely inverted. The length of immobilisation, prognosis, and



Fig. 653. Antero-posterior radiograph of a third degree adduction fracture.



Fig. 654. Lateral film of the same case to show the separation of the posterior fragment, but little displacement.

A fuller consideration of the adduction fracture of the medial malleolus will be found in the later paragraphs on fractures of the medial malleolus.

a severe third degree lesion and requires the same treatment as detailed for a third degree external rotation injury.

FRACTURES BY ADDUCTION FORCE

It has already been pointed out that there are two elements in the force commonly called adduction, firstly direct slide of the talus medially, and secondly, rotation of the talus medially or tibial flexion. As a result the first degree lesion may be represented by an avulsion of the fibular malleolus near its tip, or a simple vertical fracture of the medial malleolus.

Adduction fractures of the ankle. First degree. Transverse fracture of the lateral malleolus below the tibio-fibular ligaments.

Vertical linear fracture of the medial malleolus.

Second degree. Both first degree lesions together with some displacement (bi-malleolar fracture).

Third degree. A second degree lesion together with fracture of the posterior margin of the tibia.

In adduction fractures the mechanism is the opposite of the abduction lesions, but there is one important variant. Adduction first puts strain on the fibula which snaps over the edge of the tibia, producing the first degree lesion with little displacement This allows strain to fall on the medial malleolus which fractures from pressure on its joint side, characterised by the fracture line running vertically. This allows medial displacement of the ankle as a whole, the second degree lesion. The third degree lesion is a very rare accompaniment of adduction injury. It consists, as before, of a combination of the second degree lesion with fracture of the posterior margin of the tibia.

The important variant in this group is the vertical fracture of the medial malleolus which occurs alone in many cases, particularly the young in whom the elasticity of the fibular ligaments allows force sufficient to cause fracture to be developed without fracturing the lower end of the fibula. There is no displacement with this lesion which is classed as a first degree lesion. The additional possibility of rupture of the fibular collateral ligaments replacing the fracture of the fibula has to be considered, but on account of the strength of these ligaments its occurrence is of great rarity.

Treatment. This resembles the treatment of the first, second and third degree external rotation lesions The corrective force on the foot must however, be applied in a lateral direction. Owing to the position of the fracture of the medial malleolus it is impossible to over-correct the displacement, though deformity may occur if the foot is everted rather than left in the neutral position.



Fig. 653. Antero-posterior radiograph of a third degree adduction fracture.



Fig. 654. Lateral film of the same case to show the separation of the posterior fragment, but little displacement.

A fuller consideration of the adduction fracture of the medial malleolus will be found in the later paragraphs on fractures of the medial malleolus.

Fractures of the lower end of the fibula associated with abduction and adduction injuries. For details of the fractures when diastasis

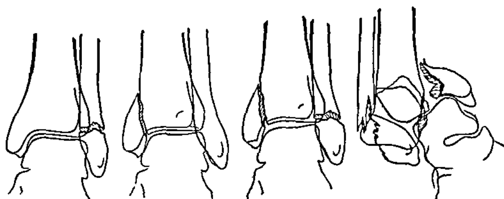


FIG. 655 A first degree adduction fracture. First variety.

FIG. 656. Snedoc variety of adduction fracture occurring where the weight falls on the medial malleolus.

FIG. 657. A second degree adduction fracture. (Second type of bimalleolar fracture.)

FIG. 658 A.P. radiograph of a third degree adduction fracture. (Compare Fig. 659.)

occurs p. 573 must be consulted. When the interosseous ligaments hold the fibula snaps transversely through the syndesmosis. In

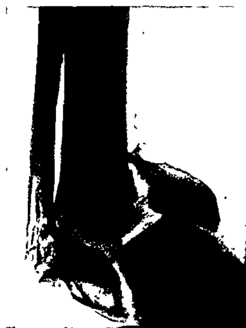


FIG. 659. Third degree adduction fracture of the ankle.

adduction injuries it is broken just below level of the *tibial surface* by being bent over the lower margin of the tibia. In abduction injuries the fracture *is a little higher, and if the lower portions of the*



Fig. 660. Ununited abduction fracture of the fibular malleolus.



Fig. 661. The same case united after intramedullary bone peg.

anterior and posterior ligaments tear it may be above the level of the tibial articular surface. It remains, however, irregularly transverse. Although in the majority of cases reduction of the malleolus is satisfactory, there are a small group of cases in which, like the medial malleolus, a satisfactory position is not achieved due probably to the interposition of soft tissue. Non-union may occur and if manipulative reduction has failed, and the position is unsatisfactory, open operation and pegging of the fibula should be undertaken. It is best to insert an intramedullary bone graft through the lower end of the fibula (Fig. 661) in late cases. In recent cases an oblique screw across the syndesnosis into the tibia may be used.

Fractures of the Medial Malleolus

These fractures deserve special consideration for they show in microcosm the influence of the forces producing the major fractures of the ankle. There are three varieties encountered, and these are shown in Figs. 664–666.

ABDUCTION FRACTURE OF THE MEDIAL MALLEOLUS. The medial malleolus is avulsed by the pull of the deltoid ligament, when the ankle is forced into fibular flexion. The line of separation is almost transverse. Wide separation may occur (Fig. 648), and on the reduction of the fracture soft tissue may be caught between the two fracture surfaces (Fig. 663). If this does not occur the swelling of the ankle may so tighten the circular fibres in the subcutaneous fascia that in order to relax the tension they may slip into the fracture line. In either case non-union may result. This is not necessarily important in an elderly subject, as good function is possible with firm fibrous union. In the young, fibrous union will be found a hindrance to sporting activity, and if the separation of the malleolus is at all obvious after manual reduction, it should be exposed and the fibrous tissue removed and the malleolus fixed in place with a single oblique screw (Fig. 652). This should be done almost immediately. After the first week the softening of the tissues makes the operation difficult. Small avulsed fragments of the malleolar tip are also best left alone.

EXTERNAL ROTATION FRACTURE OF THE MEDIAL MALLEOLUS. When the foot is externally rotated the maximal strain is placed on the anterior fibres of the deltoid ligament The tendency for the bone to yield at right angles to the pull results in an oblique line of fracture, which may appear somewhat spiral in the antero-posterior film, but is oblique with a sharp point forwards in the lateral film. Although soft tissue is less likely to be caught in this fracture failure of satisfactory manual reduction demands screw fixation. Fixation

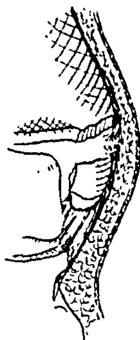


FIG. 662. Fracture of the medial malleolus by adduction. The periosteum and soft tissues fall in between the fractured surfaces.

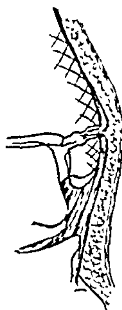


FIG. 663. On spontaneous reduction of the separation, they remain caught between the fractured surfaces, causing non-union.

is, however, often needed in order to assist in stabilising the ankle in external rotation injuries (see below).

ADDUCTION FRACTURES OF THE MEDIAL MALLEOLUS. The fissure fracture produced is a vertical one, and the malleolus is occasionally

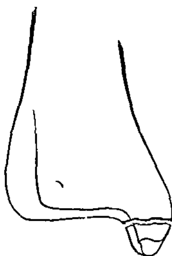


FIG. 664. Transverse abduction fracture of the medial malleolus.

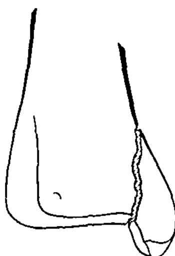


FIG. 665. Vertical adduction fracture of the medial malleolus.

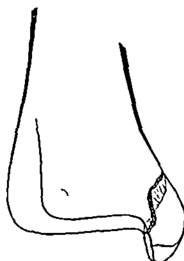


FIG. 666. Spiral oblique fracture of the medial malleolus due to a combination of abduction and external rotation violence.

anterior and posterior ligaments tear it may be above the level of the tibial articular surface. It remains, however, irregularly transverse. Although in the majority of cases reduction of the malleolus is satisfactory, there are a small group of cases in which, like the medial malleolus, a satisfactory position is not achieved due probably to the interposition of soft tissue. Non-union may occur and if manipulative reduction has failed, and the position is unsatisfactory, open operation and pegging of the fibula should be undertaken. It is best to insert an intramedullary bone graft through the lower end of the fibula (Fig. 661) in late cases. In recent cases an oblique screw across the syndesnosis into the tibia may be used

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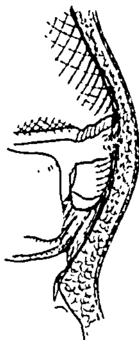


Fig. 662. Fracture of the medial malleolus by adduction. The periosteum and soft tissues fall in between the fractured surfaces.

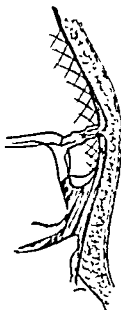


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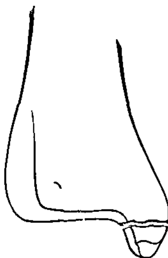


Fig. 664. Transverse abduction fracture of the medial malleolus.

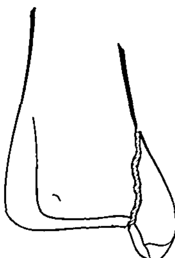


Fig. 665. Vertical adduction fracture of the medial malleolus.

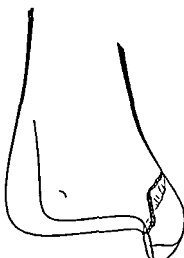


Fig. 666. Spiral oblique fracture of the medial malleolus due to a combination of abduction and external rotation violence.

a little elevated. Manual reduction is almost invariably successful, and there is no risk of non-union, or soft tissue inclusion. Operation is therefore only required in the very rare case in which reduction is imperfect due to the inclusion of a bone fragment or upwards displacement.

Screwing the medial malleolus. This is a comparatively simple procedure, and the indications for it when the medial malleolus has been unsatisfactorily reduced have been outlined. It is, however, a very valuable step in stabilising the ankle and in producing perfect reduction of many displaced fractures of the fibular malleolus found in second and third degree external rotation and abduction injuries. If the medial malleolus is perfectly reduced, the talus is pulled into position by the deltoid ligament, and the attachments of the fibula to the lateral side of the talus automatically pull the fibular malleolus into position. There are few exceptions to this, and in them it may be necessary to expose the fibula and fix the fracture, usually with a screw transfixing the malleolus and the syndesmosis. Such a screw will have to be removed later to permit the usual movements at the syndesmosis. The most common cause of failure to reduce the fibular malleolus satisfactorily is its being broken about the level of the tibial groove. This occurs characteristically in abduction or adduction fractures. If the malleolus is tilted there is not enough bone left above to press back into position by the soft parts, and though the tip may be in good position, the malleolus may remain tilted laterally. Even in complete diastasis the reduction of the *medial malleolus by a single screw is all that is needed in most cases.*

The posterior tibial flake. See p. 578.

Compression Injuries

1. Posterior marginal fractures (Figs. 578–579).
2. Anterior marginal fractures (Fig. 671).
3. Comminuted fractures of the lower end of the tibia (Fig. 667).

Anterior and posterior marginal fractures may result from falls on the foot. With the foot in plantar flexion the force is transmitted to the posterior lip of the lower surface of the tibia and a posterior marginal fracture results. This fracture is apt to be followed by displacement, and if the fragment is large enough it may carry the posterior lip of the tibial gutter with it, and, if the anterior tibiofibular ligament separates, wide displacement with a third degree fracture may result. In practice both compression and external rotation usually act together. Occasionally the posterior margin may be split off by the rotation of the cylindrical talus in the curve of the tibia, under pressure. This may produce a fine fissure with



FIG. 667. A severe adduction compression fracture of the ankle.



FIG. 668. Lateral view of the same case showing an anterior marginal fracture.



FIG. 669. The position achieved by open reduction and fixation with three screws.



FIG. 670. Lateral view after reduction and screwing.

very little separation, though if the force continues a third degree lesion may result.

Anterior marginal fractures result from falls in which the foot passes into dorsiflexion and the tibia tends to slide backwards. This accident is less common than falls in plantar flexion and the shallowness of the anterior lip does not allow such pressure to be developed on the anterior margin as the posterior. A fissure fracture may occur which in the same manner as a posterior marginal fracture destroys the stability of the joint. Compression fractures of the anterior margin of the tibia may occur from pressure against the neck of the talus, which may be fractured.

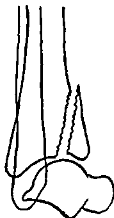


Fig 671 An anterior marginal fracture of the tibia due to compression. In marginal fractures due to forced dorsiflexion a much smaller chip of bone is displaced, or the anterior margin is merely crushed.



Fig. 672. Posterior marginal fracture of the tibia occurring alone, due to sudden compression strain.

As these fractures, with the exception of the last named, involve the weight-bearing surface of the bone, it is important for the avoidance of subsequent traumatic arthritis that they be reduced perfectly and this often necessitates open operation. An anterior approach is used for *anterior marginal fractures* and a *postero-lateral* approach for posterior marginal fractures. A single screw is used under radiological control.

Post-operatively after a week's rest in a complete plaster early exercises are commenced if the lesion is an isolated one. In those

few cases without displacement, a similar régime may be tried. No weight bearing is permitted for ten to twelve weeks to allow the joint surface to heal satisfactorily. In spite of this the accident is likely to be followed by traumatic arthritis in a longer or shorter time (see Fig. 579).

Gross comminution of the tibial surface may occur after such accidents as land mine explosions, or the tibial surface may be involved in fractures running down from the shaft. These latter cases may not show much displacement. Where displacement is gross and the joint surface is destroyed reduction of the parts under manual traction or skeletal traction is carried out and the foot immobilised at right angles and in the mid-position between inversion and eversion. A painless ankylosis is hoped for in this position. If there is



Fig. 673. Ligament traction fracture of the medial malleolus. This can be regarded as a minor variety of the first degree abduction fracture.

any possibility of return of function at the ankle joint open operative restoration of the parts has to be considered. If this is out of the question the ankle should be treated by skeletal traction and early non-weight bearing exercises.

Mal-united fractures in the ankle region. Fractures may be seen some time after their occurrence, and in the absence of any treatment union may have occurred in poor position. The most common deformity is an eversion of the heel, with a valgus deformity of the ankle due to the talus moving laterally with the angled fragment of the fibula. The most important single cause of this is too early walking, particularly in ill-fitting plaster casts applied before the swelling around the ankle has subsided. It is for this reason that the late application of the plaster and the careful use of control X-rays has been insisted upon in second and third degree fractures.

If a period of not longer than six to eight weeks has elapsed, it is possible to correct the deformity by forcible manipulation with a Thomas's wrench or the osteoclast. The aim is to get the upper surface of the talus in alignment with the lower surface of the tibia and parallel to the ground. After reduction the ankle is treated as for a fresh fracture.

In older cases the benefit likely to occur from operation must be carefully weighed. In the presence of a traumatic arthritis no improvement need be expected, and if serious disablement is present an arthrodesis may be necessary. In cases in which the principal defect appears to be a valgus deformity, and the joint is normal, an osteotomy of the tibia above the joint may improve the mechanical function of the joint and save the development of a later arthritis. More elaborate operations on both malleoli to recreate the conditions of the fracture are not satisfactory.

In a few cases fractures of the medial malleolus are reluctant to unite owing to the inclusion of soft tissues between the fracture surfaces. Open operation with freshening of the fracture surfaces and a small bone peg driven in from below will result in rapid union and restoration of painless function of the ankle. Rarely the fibular malleolus has to be treated in the same way (Fig. 661).

FURTHER READING

D'Arcy Power. "Pott's Fracture" (a record of Pott's own case), *Brit. J. Surg.*, 1922–23, **10**, 433.

Ashurst and Bromer. "Classification and Mechanism of Fracture of the Leg Bones involving the Ankle" (a full and thorough review of ankle lesions with copious bibliography on which part of this chapter is based), *Arch. Surg.*, 1922, **4**, 51.

Speed and Boyd. "Operative Reconstruction of Malunited Fractures about the Ankle Joint," *J. Bone and Joint Surg.*, 1936, **18**, 270.

Aitken. "The End Results of the Fractured Distal Tibial Epiphysis," *J. Bone and Joint Surg.*, 1936, **18**, 685.

McFarland. "Traumatic Arrest of Epiphyseal Growth at the Lower End of the Tibia," *Brit. J. Surg.*, 1931, **19**, 78.

Dickson. "Posterior Marginal Fracture of the Tibia," *Surg. Gynæ. and Obstets.*, 1933, **56**, 525.

Campbell, W. G. "The Treatment of Ankle Fractures," *Lancet*, 1938, *ii*, 872.

Bonnin, J. G. "The Hypermobile Ankle," *Proc. Roy. Soc. Med.*, 1944, **37**, 282.

Berridge and Bonnin. "The Radiographic Examination of the Ankle Joint, including Arthrography," *Surg. Gynæ. and Obstets.*, 1944, **79**, 353.

Bonnin, J. G. "Injuries to the Ankle," 1950. London, Wm. Heinemann (Medical Books) Ltd.

CHAPTER XXXIII

FRACTURES OF THE TARSUS, METATARSUS, AND TOES

Surgical anatomy. Of the tarsal bones, the talus and calcaneus stand out as of exceptional interest. The remaining bones are irregularly quadrilateral, cancellous tissue bones covered with a thin layer of compact bone, which are consequently only liable to compression and ligament traction fractures.

Talus. The most interesting point to be noted about this bone apart [illegible] [illegible]out *any muscular* [illegible] This obviously necessitates some special mechanism in addition to [illegible] [li]gaments to *retain* the bone *in situ*. This is found in the deep nature of the tibio-fibular mortice, and the oppose[illegible] calcaneal joint, [illegible] quadrilateral bony wall. The lateral surfaces are further guarded by the strong collateral ligaments of the ankle passing to the calcaneus. The anterior and posterior aspects are less well protected and are the regions *through which dislocation occurs.* The weakest point of the bone is the neck, where the compact bone is very thin and the bone is grooved by the deep sulcus of the talus. *The posterior and lateral processes of the talus require* mention as they are liable to injury.

Development. The most *important point to notice is the occasional* ossification of the posterior process of the bone from a separate centre. This may give rise to suspicion of fracture. In a certain number of cases this centre remains unfused with the body forming the os trigonum, which may also cause confusion (Fig. 28).

Calcaneus. The irregular shape of this bone renders it liable to a multiplicity of fractures. It is important to note the slight curve of the bone which looks medially, and into which the reniform clamp face of the compression clamp fits, lying just below the sustentaculum tali. In normal bones the line made by joining the upper margin of the tuberosity and the highest point of the posterior talo-calcaneal joint with a line joining this point and the angle of the bone is known *as the salient angle (joint-tuberosity angle).* It varies from 20° to 40°, and is a useful measure of the depression of the *posterior talo-calcaneal joint in compression fractures* of the calcaneus. *Its* variability demands a control picture of the opposite leg for comparison.

Development. *An epiphysis for* the posterior surface of the bone appears about five to eight years, and unites at sixteen to twenty-two years.

Accessory bones of the foot. The frequent occurrence of accessory bones in the foot is important, as if one is not aware of them fracture is often suspected. Such bones may be sesamoid bones which normally appear at certain sites, or they may be true accessory bones which represent persistent phylogenetic remnants. They have the following characteristics.

1. They appear at known sites.
2. They are usually bilateral.
3. They have clear and well-defined peripheries.

From these points it is clear how they should be detected. The accurate

examination of the film, combined with a comparative X-ray of the normal foot will exclude fracture. Common accessory bones are :—

1. The os trigonum, resembling a fracture of the posterior process of the talus.

2. The os Vesalianum, at base of the fifth metacarpal (see later).

3. Accessory navicular. A small bone occasionally present in the region of the navicular tuberosity. (Os tibiale externum.)



FIG 674. Lateral view of the calcaneus showing the salient angle or joint-tuberosity angle which varies from 20° to 40°. A sesamoid bone is also to be seen in the tendon of the peroneus longus, which has been mistaken for a fracture of the anterior end of the calcaneus

4. The talo-navicular bone. Lying on the dorsum of the foot between the talus and the navicular.

These are the most common accessory bones, but there are some sixteen other rarer ones.

Fractures of the Talus

1. Fracture of the neck
2. Fissure fractures of the body.
3. Crushing of the head with fragmentation
4. Fractures of the posterior process
5. Traction fractures of ligamentous insertions.
6. Fractures of the medial and lateral inferior borders.

The question of fractures of the talus is closely bound up with dislocation of the talus, which may occur at the ankle, the sub-taloid joint, and the talo-navicular part of the mid-tarsal joint. The

common usage of the term sub-taloid dislocation ignores the involvement of the talo-navicular joint. When the neck of the talus is fractured and the body of the talus dislocated the talo-navicular joint and anterior talo-calcaneal joint remain intact, and the post [illegible]

and the classification of such lesions presents some difficulty. The prime purpose of a classification is a guide to ordered thought and an aid to memory. The more facts which can be brought into line with any classification the better unless the classification is rendered too



FIG. 675. Dislocation of the talus at the ankle without fracture. Single dislocation of the talus without fracture.

cumbrous. It is tempting to classify lesions under their causative violence as has been done for injuries to the ankle. Desirable though this is, the complicated lesions being due in many cases to a combination of forces, or a succession of injuries such a classification is too simple to be correct. It is therefore suggested the dislocations and fracture dislocations of the talus should be classified on an anatomical basis which, if academic, has the virtue of being familiar, simple, and covering more contingencies than one based on mechanism.

Classification. SINGLE. Involving one joint only. This is *only possible at the ankle, and the injury may be due to any combination of the forces described in the previous chapter.* For

simplicity single dislocation of the talus is usually limited to dislocation at the ankle joint without fracture. If a fracture has occurred it is described as a fracture dislocation of the ankle.

DOUBLE. Two joints are involved :—

1. Without fracture. Sub-taloid (subastragaloid) dislocation. The injury which may be due to forced inversion or eversion of the foot with medial or lateral dislocation of the talus, involves the talo-calcaneal and talo-navicular joints *(Figs. 678, 679).*

2. With fracture of the neck of the talus. These injuries most commonly occur as the result of forced dorsiflexion of the foot (" rudder bar injuries "). The first stage of the lesion is the fracture of the neck of the talus without displacement. A continuation of the forces acting produces dislocation at the posterior talo-calcaneal joint and a variable degree of displacement of the body.

TRIPLE. In this group all three joints are involved, the equivalent of total dislocation of the talus (Fig. 683).

Any of these lesions may be complicated by fractures of the processes or margins of the bone or damage to the mid-tarsal joint.

Fractures of the Talus

Fracture of the neck of the talus. This is a dorsiflexion injury, and occurring without dislocation of the body of the bone will be described here. The attachments of the bone being intact there is no danger of avascular necrosis. Damage to the anterior margin of the tibia may be serious and result in traumatic arthritis of the ankle joint. More commonly the damage is only of a minor character which has to be carefully sought for.

TREATMENT. This consists in immobilising the foot in plaster in the normal plantigrade position for eight weeks without weight bearing when there is no displacement. The usual remedial exercises are begun after this, and some weeks may elapse before the resulting stiff foot returns to normal.

Great care must be taken that an accompanying dislocation of the posterior sub-taloid joint which has reduced itself incompletely is not overlooked. It is necessary to immobilise such cases in *plantar flexion* to reduce the deformity. Fracture of the neck of the talus with displacement of the body is twice as common as without (see below).

FISSURE FRACTURES OF THE BODY These may occur from compression and remain undisplaced Treatment is similar to fractures of the neck of the talus. Compression fracture of the head of the talus is irreducible and has to be treated in a similar manner.

FRACTURES OF THE POSTERIOR PROCESS. Great care has to be taken not to confuse the ununited secondary centre of the posterior

tubercle with this fracture. This is the so-called os trigonum illustrated in Fig. 28. The lesion when present is due to forced plantar flexion, and in the absence of other injuries can be treated by early mobilisation of the foot and weight bearing. Where a larger fragment is involved, carrying with it part of the articular surface (Fig. 676) excision of the fragment is the best policy. Traction fractures of the ligamentous insertions are not as common as the similar lesions of the malleoli. Treatment is similar (p. 584). Fractures of the medial and lateral margins should raise suspicion of marked displacement which has spontaneously reduced itself. Rarely they occur alone. They require a short period of rest and then mobilisation.



FIG. 676. Fracture of the posterior process of the talus. The almost total detachment of this process from its blood supply renders its removal necessary.

Subtaloid (subastragaloid) dislocation (double or incomplete).

(*a*) With medial displacement of the foot (Fig. 677).

(*b*) With lateral displacement of the foot (rare) (Fig. 678).

As the result of either inversion strain or eversion combined with rotation the calcaneus and navicular are twisted from the lower surface of the talus. This probably occurs with the foot in the plantigrade position under some pressure, or else the talus would dislocate



FIG. 677. Medial subtaloid dislocation, showing the dangers of failure to reduce the displacement quickly. An area of skin gangrene has developed over the prominent head of the talus.

at the ankle joint. The talus retains its normal position, but the rest of the tarsus is drawn up on one or other side of it. If laterally, the tip of the fibula is often fractured. The navicular is drawn up anteriorly by the tension in the tibialis anterior, with increase in the longitudinal arching of the foot and apparent plantar flexion of the talus.

The signs and symptoms are gross, and while they may resemble a total dislocation of the talus (*q.v.*) the condition is easily recognised by radiography.

TREATMENT. Manipulative reduction is usually easily carried out, and once reduced the condition is stable. The foot is immobilised in plaster in the normal plantigrade position. Weight bearing should not be permitted for the first month and the plaster should be retained for eight weeks. A satisfactory recovery follows, but persistent stiffness of the hind foot and mid-tarsal arthralgia after walking may remain. A surgical shoe with a built-in vagus insole should be provided in such cases. Avascular necrosis of the talus does not follow this accident.

Fracture of the neck of the talus with dislocation of the posterior talo-calcaneal joint. The knowledge of this classical flying accident has recently been considerably increased by the study of the cases in the R.A.F The injury is a dorsiflexion one in which the neck of the talus is sheered off against the lower margin of the tibia, which frequently shows signs of damage. As a result of the forward pressure on the foot at the time of the accident the fractured neck of the talus is often impacted into the body, and on plantar-flexion of the foot to a right angle the body of the talus is drawn down into plantar flexion The only method of disimpacting the fragments and getting them into normal position is to forcibly plantarflex the foot, when, following disimpaction, the fragments usually slide into position. In a few cases they will not reduce satisfactorily, due to wedging of comminuted fragments between the neck and the body. Two groups of cases can be recognised according to the displacement of the body of the bone

1. Those in which the talo-fibular and talo-tibial ligaments retain the body of the bone in position
2. Those in which all the ligamentous attachments of the body are ruptured and the body assumes one of many diverse positions

The distinction is important, as in the first group of cases a very limited percentage of the cases (under 50 per cent) will undergo avascular necrosis, while in the second group it is almost inevitable. It is, however, worth noting that necrosis does not necessarily occur, and a clinical trial should be given before arthrodesis of the ankle, in all cases. I have recorded one case which was not followed by

avascular necrosis, and there is one case in the literature in which the talus was removed, washed in saline and re-inserted and survived.

Treatment. When the body lies in normal position. The



Fig. 678. Double dislocation of the talus. Lateral view of a sub-taloid (sub-astragaloid) dislocation of the tarsus.

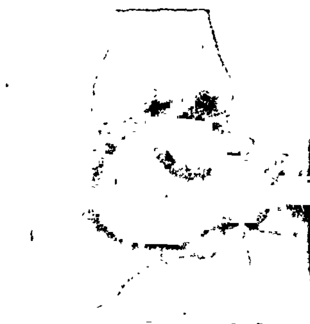


Fig. 679. Antero-posterior view of the same case.

head of the talus is brought into line with the neck of the bone by plantar flexion and slight inversion or eversion. The position of inversion or eversion assumed is opposite to the displacement at the time of the injury. Careful check radiography is necessary to be

at the ankle joint. The talus retains its normal position, but the rest of the tarsus is drawn up on one or other side of it. If laterally, the tip of the fibula is often fractured. The navicular is drawn up anteriorly by the tension in the tibialis anterior, with increase in the longitudinal arching of the foot and apparent plantar flexion of the talus.

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The distinction is important, as in the first group of cases a very limited percentage of the cases (under 50 per cent.) will undergo avascular necrosis, while in the second group it is almost inevitable. It is, however, worth noting that necrosis does not necessarily occur, and a clinical trial should be given before arthrodesis of the ankle, in all cases. I have recorded one case which was not followed by

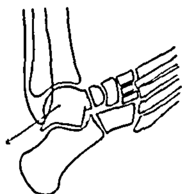


Fig. 681. The mechanism of posterior fracture dislocation of the talus. The arrow shows the direction of the resultant forces in the dorsiflexed foot.

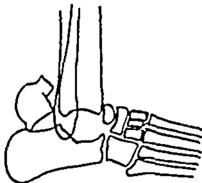


Fig. 682. One position of the dislocated body of the bone. The more usual displacement is shown in the succeeding figure.

follow. There is, however, every chance that, though the function of the ankle in twelve months' time may be good, early degenerative arthritis will set in. Should weight bearing be permitted during this period the compression of the bone and arthritis is inevitable. When painful and advanced, arthrodesis of the ankle must be carried out. Tibio-calcaneal fusion, leaving the head *in situ*, is most satisfactory.

Late and irreducible cases. When contraction of tissue and adhesions have occurred reduction of the body may be impossible and excision is inevitable. It should be followed by immediate tibio-calcaneal fusion.

Total dislocation of the talus (triple or complete)

This uncommon lesion is usually the result of falls with the foot in inversion. Rupture of the fibular collateral ligament allows the escape of the talus in front of the fibula, and dorsiflexion of the foot causes it to lie across the foot in front of the anterior tibial margin. This is antero-lateral dislocation (Fig. 683). Antero-medial dislocation from eversion injuries accompanied by rupture of the deltoid ligament occur The position of the talus is very variable, and it has been found completely reversed on its long axis. (The axis running from the posterior tubercle through the centre of the neck.) Complete posterior dislocation is recorded but is extremely rare.

Symptoms and diagnosis. There is always a history of a fall from a height, but this may be merely that from a chair. Gross swelling and deformity are present. The displaced body of the talus may be palpated lying anteriorly or posteriorly, where it may be obscured to some extent by the tendo-calcaneus. It can be recognised by the feel of its saddle-shaped articular surface. In compound cases this is frequently visible through the wound. If the skin is not broken it is under great tension and requires urgent attention to

certain the fracture is reduced in both planes. Union is apt to be slow and the plantar flexed position must be maintained for eight to ten weeks. A plaster in the plantigrade position follows for a further fortnight, and if radiological evidence of union is satisfactory weight bearing is permitted in it for a further fortnight. It is then removed and rehabilitation commenced.

WHEN THE BODY IS DISPLACED. The displacement of the body is variable. It is most commonly postero-medial (Fig. 685), but may be postero-lateral or anterior. Reduction must be carried out immediately to avoid sloughing of the skin over the displaced body, undesirable pressure on vessels and nerves, and avascular necrosis. Reduction may be manipulative, or operative, and it is worth



FIG 680 Avascular necrosis of the body of the talus following a mine explosion underfoot. Fracture of the neck of the talus without displacement

remembering that skeletal transfixion of the body by a thin Steinmann's pin may assist. In general, owing to the numerous minor complicating factors present, such as fracture of the medial malleolus, comminution of fragments, open operation is to be recommended. While the possibility of reducing the vascular supply of the bone still further exists, undesirable soft tissue tension can be eliminated by evacuation of the hæmatomas. Retention of the talus after open reduction may be by plaster, but control of the fragments may only be obtained by the insertion of a screw through the neck of the talus into the body Fracture of the medial malleolus, if associated, should be pegged back into position.

Avascular necrosis is shown by an increase in the density of the body of the bone (Fig. 680) compared with the surrounding bones. If the bone is immobilised replacement with living bone will slowly

produce pressure on the posterior tibial nerve or on the tendons of the flexor hallucis longus and flexor has been completely severed from its attachments. There are at least two recorded cases where the loose talus has been washed in saline and returned to its position with complete success.

Reduction is most readily accomplished by skeletal traction. Antero-medial dislocations slip back more easily than antero-lateral

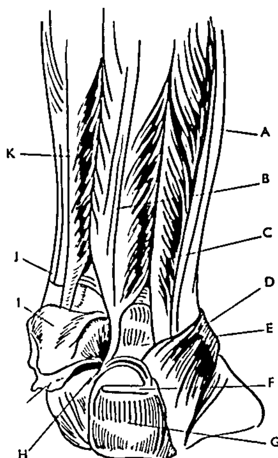


FIG. 685. Drawing to represent the position of the talus found at operative reduction of a posterior medial fracture dislocation.
A. Peronæus longus B. Flexor hallucis longus. C. Peronæus brevis. D. Peroneal retinaculum. E. Articular capsule of the ankle. F. Cut tendo Achilles G. Tuber. calcanei. H. Tendon of flexor hallucis longus. I. Displaced talus. J. Tendon of tibialis posterior K Flexor digitorum longus.

ones which are obstructed by the deep anterior margin of the fibula. In posterior dislocations there may be difficulty owing to the bone becoming button-holed by the tendons previously mentioned. In either anterior or posterior lesions if manipulative reduction fails one should proceed at once to operative reduction, which is best carried out on the traction frame so that the skeletal traction can be continued. The reduction is carried out through a vertical incision over the displaced bone.



FIG 683. Triple dislocation of the talus. Antero-posterior film showing antero-lateral dislocation of the body of the bone, which lies in front of the fibula.



FIG. 684. Lateral view of the same case, showing the long axis of the talus lying in the transverse plane.

avoid the onset of gangrene. With the anterior dislocations the strain on the skin is greater than with posterior cases as there is more room behind the ankle posteriorly. Posterior dislocations may

produce pressure on the posterior tibial nerve or on the tendons of the flexor hallucis longus and flexor has been completely severed from its attachments. There are at least two recorded cases where the loose talus has been washed in saline and returned to its position with complete success.

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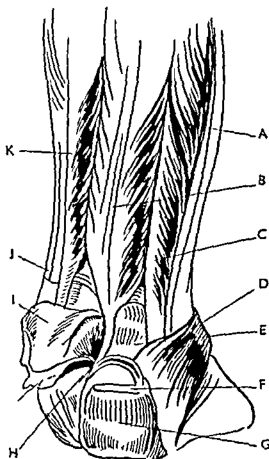


FIG. [illegible]

[illegible] F. Cut tendo Achilles. G. Tuber. calcanei. H. Tendon of flexor hallucis longus. I. Displaced talus. J. Tendon of tibialis posterior. K. Flexor digitorum longus.

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In posterior dislocations the traction frame must be turned on its side to facilitate the approach. By making a clear exposure the obstructing bony points or the stretched ligaments can be seen, and the bone slipped back with levers. The wound is then closed with the usual precautions and the leg plastered. In compound cases the wound is excised and then the bone replaced under observation, before suture. The wire in the calcaneus may be left if desired for light traction. In fresh cases the plaster is split, or padded.

After-treatment. The limb is rested on a Braun's or Thomas splint. When the wound has healed and swelling has subsided, the leg is put in a plaster to the knee. Walking is not permitted till there is evidence of good union of any fracture, or a restored blood supply in cases of dislocation of the body or whole bone. At the end of five to six weeks, however, the plaster may be guttered and exercises to the ankle commenced if the X-ray findings are satisfactory. These were more fully discussed in an earlier chapter. If avascular necrosis has commenced weight bearing will hasten the dissolution of the bone. The patient must rest till either the circulation is restored, or the bone has degenerated.

Late cases. Where the case is seen some time after the accident the chances of survival of the bone are much diminished. After forty-eight hours' displacement the majority of cases undergo avascular necrosis even if reduced. It is, however, always worthwhile trying up to the end of the first week, after which tibio-calcaneal arthrodesis is to be recommended, either partial or complete.

Fractures of the calcaneus. Any person who falls from a height of three feet or more on to their heels and complains of persistent pain afterwards should be suspected of a fracture of the calcaneus. The fracture which may occur varies from a fissure without displacement to a gross crushing injury. The sequelæ are apt to be disproportionately severe if the clinical and radiological appearances of deformity are taken as the criteria of judgment. Although several well recognised varieties of fracture occur, due either to the structure of the bone or the uniformity of mechanism, there are two great clinical groups of cases.

1. In which the posterior talo-calcaneal joint is not involved. This includes fractures of the tuberosity and processes and minor fissures without displacement Serious sequelæ do not occur.

2. In which the posterior talo-calcaneal or sub-taloid joint is fractured or altered in alignment. Thus group is liable to be followed by a sub-taloid arthritis which may be seriously disabling, and in any case is followed by limitation of movements at the sub-taloid

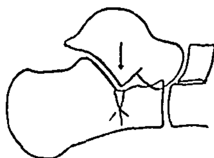


FIG. 686. Mechanism of fracture of the calcaneus. First stage.

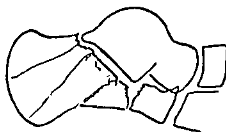


FIG. 687. Second stage. The bone is fissured, and the posterior articular surface driven into the cancellous bone of the body.

joint and an inability to walk comfortably over irregular ground.

SIGNS AND SYMPTOMS. The deformity may be either negligible or very gross. When obvious it consists of shortening and eversion of the heel and flattening of the arch. Frequently this is obscured by gross swelling of the ankle. The local pain and tenderness is often acute, amounting to hyperæsthesia. In a few cases it may be possible to appreciate with the fingers the shortening of the distance from the sustentaculum tali to the medial malleolus. In some cases the broadening of the bone is shown by a swelling behind the lateral malleolus. The condition is frequently bilateral and in falls on to the feet from a height, or mine explosions at sea where there is a violent upward thrust of the deck, the common association of a compression fracture of the 12th dorsal or 1st lumbar vertebra must be borne in mind.

MECHANISM The weight of the body drives the sharp angle of the talus into the body of the calcaneus just anterior to the posterior talo-calcaneal facet. The lateral wall of the calcaneus breaks here, just above the peroneal tubercle. The weight then falls on the sustentaculum tali which is broken so that the whole weight is taken by the posterior articular facet which is either fragmented sometimes with a long sagittal fracture running to the tuberosity (Fig. 691), or driven deep into the cancellous tissue of the bone. In either case the salient angle is obliterated, though to greater degree in the latter case. In lesser injuries the bone may have a process broken off, or it may fissure in the line of the lamellæ with no displacement. The anterior end of the bone is remarkably infrequently injured. In severe

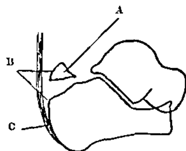


FIG. 688. "Beak" fracture of the calcaneus A Triangular fragment of bone. B. Areas of the tuber calcanei in contact with the bursa below the tendo-Achilles. C. Tendo-Achilles.

lesions the bone is fragmented, broadened, the salient angle completely obliterated, and the head of the talus *partly dislocated in* an upward direction. The fractures of the bone may be summarised as follows :—

1. " Beak " fractures (5 per cent.) (Fig. 688).

2. Fractures of the medial tuberosity (13 per cent.) (Fig. 689).

3. Fractures of the sustentaculum tali alone (4 per cent.).

4. Fractures of the body without displacement of the joint surfaces (25 per cent.).

5. Fractures of the body involving depression of the posterior articular area alone (30 per cent.) (Fig. 690).

6. Fractures involving the displacement of the whole of the posterior articular facet, fracture of the sustentaculum tali, fissuring *of the bone, and obliteration of the salient angle, with or without* dislocation of the talo-navicular joint (26 per cent.) (Fig. 691).

X-RAY EXAMINATION. Accurate lateral views of the bone are necessary together with a plantar view of the bone, taken with the foot in dorsiflexion and the tube at an angle of 45° to the plate which lies under the heel. Only in this film can fractures of the sustentaculum be seen, and shortening and broadening of the calcaneus be appreciated. It is advisable to have two similar views of the sound heel taken at the same time for comparison.

ANÆSTHESIA. In fresh cases local anæsthesia can be used, but it is not as satisfactory as when used elsewhere, and requires to be supplemented by gas for the compression of the bone. More satis*factory is intravenous or spinal anæsthesia, obviously the choice in* bilateral cases. General anæsthesia is satisfactory, and though the duration of the anæsthetic may be long the patient does not need to be kept deep.

1. " BEAK " FRACTURES. In these cases a small triangle of bone is elevated from the dorsum of the tuberosity. The base of the triangle corresponds to the bursal area of the tuberosity, so that *tendon traction can play no part in the lesion and its mechanism* is uncertain It is possibly due to lateral pressure. Reduction is usually easily accomplished by relaxing the tendo-Achilles by flexing the knee, and plantar flexing the foot, and pushing firmly with the thumbs on either side of the tendon. The foot is then put up in slight plantar flexion for three weeks in a walking plaster which is moulded carefully around the ankle.

2. FRACTURES OF THE SUSTENTACULUM TALI. Displacement is medial and small. The line of fracture is sagittal and runs through the groove for the *flexor hallucis longus. After swelling has subsided* a plaster is applied for three weeks, to prevent inversion.

3. FRACTURES OF THE MEDIAL TUBEROSITY. These usually show

little displacement, but if it is present it is corrected at the end of two to three days' rest with a compression clamp. A walking plaster is then applied for three to five weeks.

Cases with no displacement may be treated by early exercises. Weight bearing will be avoided on account of pain for the first week, but can be commenced as soon as it is comfortable.

4. Fractures of the body without displacement. These require rest and elevation till swelling has subsided. Weight bearing

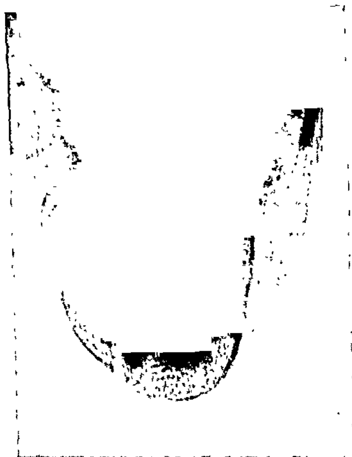


Fig. 689. Fracture of the medial tuberosity of the calcaneus (os calcis).

is not permitted, but active non-weight bearing exercises are carried out. The patient is allowed up on crutches with the ankle supported by a firm bandage A decision as to when weight bearing should be permitted is based on the position and extent of the fracture, the mobility of the hind-foot, and the amount of pain on pressure on the heel. The time will vary from four to eight weeks. Persistent trouble of a serious nature should not follow this type of injury.

5. Fractures of the body with depression of the posterior talo-calcaneal joint. Even pressure on the articular facet may drive it deeply into the cancellous tissue of the body of the bone.

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Cases with no displacement may be treated by early exercises. Weight bearing will be avoided on account of pain for the first week, but can be commenced as soon as it is comfortable.

4. FRACTURES OF THE BODY WITHOUT DISPLACEMENT. These require rest and elevation till swelling has subsided. Weight bearing

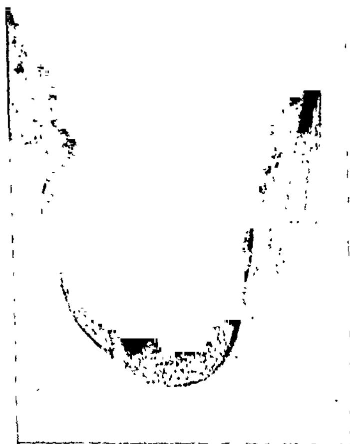


FIG. 689. Fracture of the medial tuberosity of the calcaneus (os calcis).

is not permitted, but active non-weight bearing exercises are carried out. The patient is allowed up on crutches with the ankle supported by a firm bandage. A decision as to when weight bearing should be permitted is based on the position and extent of the fracture, the mobility of the hind-foot, and the amount of pain on pressure on the heel. The time will vary from four to eight weeks. Persistent trouble of a serious nature should not follow this type of injury.

5. FRACTURES OF THE BODY WITH DEPRESSION OF THE POSTERIOR TALO-CALCANEAL JOINT. Even pressure on the articular facet may drive it deeply into the cancellous tissue of the body of the bone.

Slightly uneven pressure with the foot inverted may sheer off the lateral half of the posterior facet. The fracture lines often run back to the tuberosity as in Figs. 690, 691.

The total deformity of the calcaneus is not gross. Elevation of the articular facet is impossible by lateral compression, and difficult by traction. Although the salient angle is reduced the disability is to some extent countered by slight plantar flexion of the talus and flattening of the angle of the calcaneus.

It must be stated here unequivocally that all immobilisation of the foot in plaster after calcaneal and tarsal injuries is very undesirable, owing to the stiffness which develops in the hind foot. Particularly undesirable is a long period in plaster with a pin transfixing the calcaneus and under traction. The adoption of one of these methods is almost inevitable if perfect anatomical reduction is the aim. As the unpleasant sequelæ are due to subtaloid arthritis, and this is due to a fracture into the joint which cannot be satisfactorily repaired in most cases, experience has shown that an active policy of massage and active and passive movement from the first results in a far greater percentage of successes than methods involving fixation. If arthritis is going to develop at the subastragaloid joint it will occur regardless of treatment and can be treated by a later subtaloid arthrodesis It is much better to do this in a foot which is mobile than in a stiff foot after months of plaster treatment.

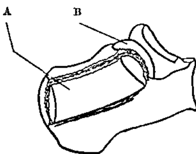


Fig. 690. Fracture of the calcaneus with displacement of the lateral side of the posterior talo-calcaneal joint A. Fractured fragment. B. Posterior talo-calcaneal joint.

In the fracture described the majority of the subtaloid joint is undamaged. The chances of avoiding subtaloid arthritis are therefore better than in Group 6 cases, and an attempt to restore the anatomical position can thus be justified. This may be done :—

(1) Open operation and packing the fragment back into place with bone chips (Palmer).

(2) The use of a spike inserted into the upper detached fragment and leverage The pin is pushed down, levering the fragment up, and the pin then incorporated in the plaster for retention Retention will be necessary for a month, after which an active regime without weight bearing is commenced (Fig. 691).

In those in which pain persists, sub-taloid arthritis is occurring and the end result resembles the unsatisfactory cases of Group 6.

6. Severe crushing fractures of the calcaneus. Owing

to the severe disability which is apt to follow such a lesion these fractures have gained a bad reputation, and to try and minimise the period of disability heroic measures have been adopted, such as immediate subastragaloid arthrodesis, or early weight bearing with



FIG. 691. Fracture of the body of the calcaneus with displacement of the lateral portion of the posterior articular surface.



FIG. 692. The same case reduced by the insertion of a spike into the upper and outer fragment and levering it into position. The spike is then incorporated in the plaster.

no attempt at reduction in order to encourage arthrodesis. This is to abandon at once any effort to obtain a normal foot. While not denying that a small number of cases will come to arthrodesis, such a nihilist attitude is not justified by the number of cases which adequately treated by the methods outlined will obtain a reasonably useful and painless foot.

The deformities met with in serious injuries may be :—

1. Shortening of the bone on its long axis.
2. Broadening of the bone.
3. Angulation of the bone open medially, an increase of its normal curve.
4. Depression of the posterior articular surface and obliteration of the salient angle, due either to this or to fracture of the body, with angulation open upwards.

Reduction *per se* is unlikely to reduce the amount of subsequent arthritis, but may reduce the strains imposed on the arthritic joints



FIG. 693. Loss of the normal concavity of the tendo-Achilles after untreated compression fracture of the calcaneus.

by restoring normal alignment. In particular, an attempt is made to reduce shortening and flattening of the calcaneus

Various methods of reduction have been devised and the important ones will be outlined.

1. PHELPS-GOCHT CLAMP. The action of this clamp is best explained diagrammatically. The clamp is so adjusted that pressure is applied above the neck of the talus, to the upper surface of the tuberosity of the calcaneus and to the under-surface of the calcaneus. By tightening this pressure the salient angle of the calcaneus can be partly restored. Reduction by this method can never be complete.

2. BY A POSTERIOR PIN. A Steinmann's pin is driven into the calcaneus from the posterior aspect. Control X-rays are taken. By comparison with the normal foot and assuming the posterior fractured portion of the calcaneus moves with the pin, it should be possible to calculate the angle through which the pin must be moved to restore the fragment to normal. This is then forcibly accomplished, and the pin incorporated in the plaster. Unfortunately the pin does not always move the posterior fragment. In simple cases this method may be effective. The after-treatment is similar to the next method.

Both the above methods correct only the obliterated salient angle, and

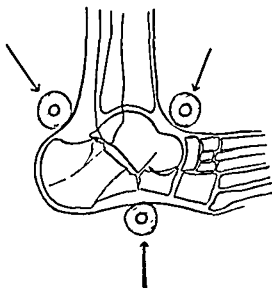


Fig. 694. The action of the Phelps-Gocht osteoclast in reducing fractures of the calcaneus. The arrows indicate the sites of the padded rollers of the clamp and the general direction of their pressure (Clamp shown in Fig. 146).

require to be combined *with compression to correct the broadening and* angulation.

3. By skeletal traction and compression. This is the method of Böhler and can be combined with continuous traction as after-treatment.

Method. A Kirschner wire or a thin Steinmann's pin is inserted in the upper posterior angle of the calcaneus. This position is necessary to avoid the pin being in the way of the compression clamp. The leg is then put up in the Böhler traction frame and the stirrup attached by a spring balance to the tightening screw. The bar under the knee has previously been well padded and an extra support bar is placed over the lower third of the tibia. From this a piece of webbing or calico is tied around the leg so as to support its lower third (previously pins were inserted in the tibia, but this is unnecessary). Traction is now made in the direction of the leg up to 40 to 60 lbs. This reduces the impaction of the subastragaloid joint and restores the salient angle. The pull is now relaxed and line of pull altered to the line of the tuberosity of the calcaneus, approximately 45° to the line of the leg. The screw traction is now tightened to 30 to 40 lbs. This reduces the shortening of the bone. While this pull is maintained the compression clamp is applied to the calcaneus, with the reniform pad on the medial side. It is screwed up to a distance of 35 mm. apart, the average width of the calcaneus, and then



Fig. 695. Severe crushing fracture of the calcaneus. The correct position for the pin.



Fig. 696. The pin in position. The shortening and broadening of the calcaneus is well shown.

immediately relaxed. Control X-rays may now be taken, and while they are being developed the traction is once more brought in line with the leg and tightened. A plaster slab is placed on the extensor surface of the limb and bandaged on. When this has set the limb is placed on a Braun's splint and a weight of 10 to 15 lbs. placed on the stirrup.

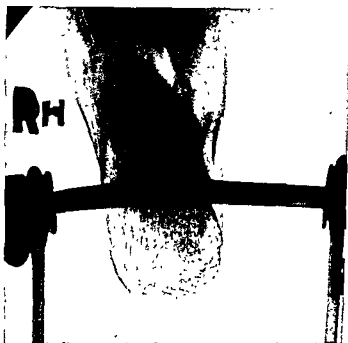


Fig. 697. *The same case after traction in the direction of the tuberosity has been applied, and the calcaneal compression clamp has been used.*

Treatment after reduction. The forces tending to reproduce the displacement are the pull of the tendo-calcaneus and the weight of the body. Weight



Fig. 698. *The final result with the calcaneus restored to almost normal appearance and a normal salient angle.*

bearing can easily be avoided, but the pull of the tendo-calcaneous is constant and difficult to counteract. Flexion of the knee is not sufficient. One may counteract this force by continuous *traction*, *or one may incorporate the*



Fig. 699. Reduction of a fracture of the calcaneus. *Traction being* applied in the direction of the tuberosity of the calcaneus.

calcaneal pin in the plaster together with another one below the tibial tuberosity, which by *maintaining* a fixed distance between the pins counteracts any tendency to compression. Both these methods have the disadvantage of producing great stiffness in the hind foot. *It* is possible that in this lies

their success, as if the movement of the sub-taloid joint is restricted or the joint ankylosed it is pain free.

In general the deformity if well reduced will not recur to its original degree and often will remain reduced if weight bearing is avoided for the first two months.

(A) CONTINUOUS TRACTION. The extensor plaster slab, as described above, is bandaged on, leaving the heel free and holding the foot in slight dorsiflexion. These bandages may be reinforced by plaster bandages if desired. The traction of 5 to 12 lbs. is maintained for four weeks if the reduction is satisfactory. The pin is then removed and the limb placed in a leg plaster for a further four weeks. At the end of the eighth week weight bearing is permitted. At the end of the twelfth week the plaster is removed and an Unna's paste stocking substituted for it, and exercises for the ankle are given.

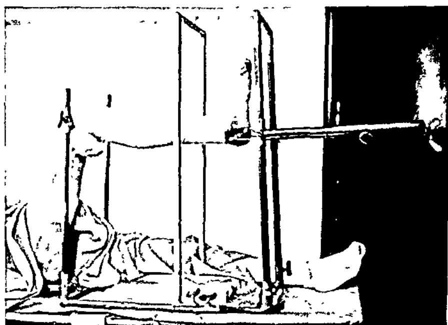


FIG. 700. The application of a plaster on the anterior surface of the limb, leaving the heel free.

(B) CONTINUOUS DISTRACTION. If this method is to be adopted a second pin is inserted below the tibial tuberosity. At the end of reduction a complete leg plaster is applied, incorporating both pins. When this is done care must be taken that the distracting force on both pins is not too great, and the tension must be reduced to 20 to 30 lbs., and the position preferably checked by X-rays before the plaster is applied. After a few days a walking iron or rubber heel is applied, and the patient allowed to get up. The plaster is worn for eight weeks, and then an ordinary walking plaster applied for two to four weeks, followed by an Unna's paste stocking.

There has been considerable discussion as to the time when reduction should be performed. It is often inadvisable in the first few days on account of shock or abrasions or other injuries, but there is no necessity to wait ten or more days. Unless there is some contraindication such as an abrasion, it is carried out on the seond or third day. Gross swelling is massaged away before the clamp is applied.

Disadvantages of skeletal reduction. Some of these have already been mentioned. It will be seen that the methods are complicated,

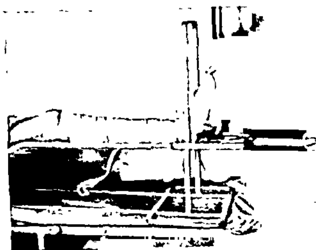


FIG. 701. The leg resting on a Braun's splint under continuous traction. Foot drop is prevented by the anterior plaster slab.



FIG 702. Same case showing the restoration of the salient angle under skeletal traction with a Kirschner wire.

often involve soft tissue compression, and are followed by a long period of fixation and traction if the deformity is not to be permitted to recur by the pull of the calf muscles. As in injuries in other

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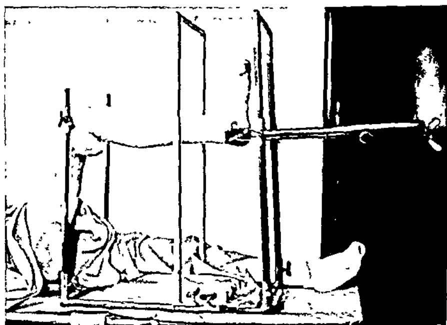


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foot is plastered at right angles. In a few cases this is not sufficient to reduce the fragments, and the talus and cuneiforms must be pulled apart by skeletal traction. A wire is inserted in the calcaneus and another in the bases of the metacarpals and traction made on the traction frame. Firm pressure is now made on the dorsum, if necessary, with a clamp. This is followed by a plaster incorporating both wires, and retained for three weeks.

Fractures of the tuberosity are occasionally met with, and the confusion which may arise from an accessory navicular tubercle has been mentioned already. A walking plaster may be required to rest the leg.



FIG. 703. *Compression fracture with anterior dislocation of the navicular.*

Fractures of the Other Tarsal Bones

Compression fractures and fractures from direct violence are not uncommon, due to the dropping of weights on the foot. Avulsion of a flake from the cuboid is a not uncommon accompaniment of severe sprain of the mid-tarsal joint

Small flakes of bone are often pulled out from the dorsum of the tarsal bones by excessive plantar flexion. This is most commonly seen in the navicular and not to be confused with the talo-navicular accessory bone. The treatment of ligament traction fractures of this type depends on the degree of associated damage.

TREATMENT. In general, unless there is a specific reason such as a compound fracture, progress is more rapid if the patient can be rested and given Faradic foot baths, massage and non-weight-bearing exercises. If it is important that the patient should be up and about without crutches rapidly a light walking plaster may be applied.

regions, reasonable function is not incompatible with deformity, and any deformity is more likely to be overcome if the hind foot has been kept flexible. The majority of cases are therefore best treated with elevation, pressure bandages in the early days and then radiant heat, massage and exercises. Weight bearing is commenced as soon as the foot feels comfortable on the ground and pain is not aggravated by it.

Cases in which it is considered unnecessary to reduce the deformity may be of two kinds. Those in which deformity is so gross that it is unlikely to be benefited by reduction and in which ankylosis of the sub-taloid joint is likely to occur, and those in which there is insufficient deformity to justify reduction. These cases are treated by elevation and early massage and non-weight-bearing exercises. These are persisted in till a stable and relatively painless foot results when weight bearing is recommended gradually.

PROGNOSIS. Three groups of cases will be found :—

1. Those in which a firm bony or fibrous ankylosis results which is pain free or reasonably comfortable.
2. Those in which a small range of pain-free movement returns.
3. Those in which increased use of the limb produces increased pain, usually followed by radiological changes of sub-taloid arthritis. These cases have persistent or increasing disability and eventually demand a sub-taloid arthrodesis.

It must be remembered that a small number of cases in which damage is done to the posterior talo-calcaneal joint will also go on to arthritis

After-treatment. The average disability period for a fracture of the os calcis of any severity is twelve months. The patient may be permanently crippled for hard manual labour. Ankle movements are unaffected, but owing to the destruction of the sub-taloid joint with subsequent traumatic arthritis there is a loss of inversion and eversion of the heel. This makes walking diagonally on a slope and on rough ground particularly troublesome. If there is no attempt at reduction made this is further complicated by the short inverted heel and flat foot. A new occupation may thus have to be found for the patient and the period of rehabilitation is likely to be long

Fractures of the Tarsal Navicular

Fractures of the navicular are the only other lesions commonly met with, though compression injuries may damage a number of bones together, or any single bone. Navicular fractures arise from severe dorsiflexion strain on the foot which fractures the bone and squeezes the fragments on to the dorsum of the foot Reduction is made by plantar flexion combined with dorsal pressure, and the

FRACTURES OF THE METATARSALS WITH DISPLACEMENT. These are usually accompanied by soft tissue damage which requires the treatment meted out to compound lesions elsewhere. It is still more important in these cases to elevate the foot and avoid swelling. The fractures are reduced by manipulation and the leg plastered. The limb is then placed on a Braun's splint. Where difficulty is met in reduction strong traction combined with the manipulation should be tried. Traction is obtained by passing stainless steel wire or strong silkworm gut through the pulps of the toes and attaching it to a wooden bar on which one may pull. While a pull is maintained



FIG. 704. Fractures of the shafts of the first, second and third metatarsals with displacement.



FIG. 705. The same case after digital extension.

an attempt is made to mould the displaced fragments into position. When this is done a leg plaster is applied. In order to retain the fragments the continuation of slight traction may be necessary. This is best carried out by the incorporation of a wire in the sole of the plaster and attaching the toe to it as in the manner of a finger wire. Slight flexion of plaster and attached toe puts traction on the metatarsal. Where possible this should be avoided and if retention of position is satisfactory early exercises should be commenced to all toes. The length of immobilisation should be no longer than necessary for the metatarsal to settle in position. At the end of this period of seven to ten days the plaster should be removed and exercises commenced of a non-weight-bearing type.

The long period of rehabilitation which must follow any immobilisation of the foot in plaster, before the patient is fit for much activity on the feet, is a serious disadvantage, and where possible rest and early active non-weight-bearing exercise is to be recommended.

Compound fractures of the tarsus. The blood supply of the foot is good, and the majority of injuries will therefore do well if primary closure of the wound can be carried out. The plaster should extend beyond the toes to prevent contraction, which occurs in injuries to the sole and calf, and to relieve the toes of the weight of the bedclothes. If the wound has to be packed and left open the prognosis is less satisfactory, and depends on the extent of the inflammation and of tissue destroyed. Provided the injury has produced no gross disturbance of the foot posture, and there is not an excessive loss of the skin on the sole, the results will be satisfactory. Late difficulties in healed cases arise from :—

1. Pressure on prominent bony areas.
2. Loss of sensation with the development of trophic ulcers.
3. Disturbances in the vascular supply, with œdema, skin lesions and pain.
4. Recrudescences of infection.

In grossly infected cases the prognosis is uncertain. In spite of a reasonably normal appearance of the foot the function is always gravely impaired. If there is gross destruction of small joints and erosion of the cancellous bodies of one or two small bones, or of the body of the calcaneus, it is probable that amputation will be needed in the end and the patient may be saved much suffering by coming to an early decision on this matter. In particular, these remarks apply to the complicated foot injuries resulting from land-mine explosions in modern warfare.

Fractures of the Metatarsals

These are similar in type to fractures of the metacarpals. They are most frequently due to crushing injuries, and so are frequently compound. With severe blows one or more metatarsals are often broken transversely at the level of the blow. Owing to the ligamentous and muscular attachments there is usually little displacement. Following such injuries it is wise to keep the foot elevated to avoid swelling of the tissues which rapidly occur in the dependent limb. Two special types of fracture will require mention, the "march" fracture and the fractures of the base of the fifth metatarsal.

FRACTURES OF THE METATARSALS WITH NO DISPLACEMENT. These are not uncommon and though the immediate pain is apt to be more severe than that from a march fracture, for reasons given under that head, the same treatment is recommended.

FRACTURES OF THE METATARSALS WITH DISPLACEMENT. These are usually accompanied by soft tissue damage which requires the treatment meted out to compound lesions elsewhere. It is still more important in these cases to elevate the foot and avoid swelling. The fractures are reduced by manipulation and the leg plastered. The limb is then placed on a Braun's splint. Where difficulty is met in reduction strong traction combined with the manipulation should be tried. Traction is obtained by passing stainless steel wire or strong silkworm gut through the pulps of the toes and attaching it to a wooden bar on which one may pull. While a pull is maintained



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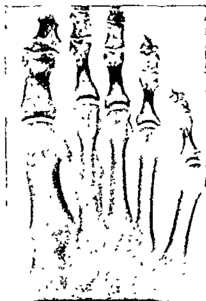


Fig. 706 A characteristic picture of a "march" fracture. The fine fissure fracture is difficult to see, but the subperiosteal new bone formation is obvious.

Weight bearing may be commenced as soon as signs of consolidation commence, usually between the third and fourth week.

March fractures. This fracture is the most common of the fatigue fractures of bone and shows the characteristic features of fatigue fractures in general. The incidence of the condition can be definitely related to the severity of exertion undertaken and the length of time the strain continues. At the same time it must be realised that *"march" fracture is only one sign of* severe foot strain, and that it is accompanied by a defective muscular tone throughout the foot and leg. For this reason *the treatment* of "march" fractures by immobilisation in plaster is to be deprecated. It results in further deterioration in muscular tone and necessitates a long period of rehabilitation on removal of the plaster. It occurs most commonly in young active adults, often associated with a sudden increase of activity, after a sedentary existence, such as typically occurs in training a recruit to march There is no definite history of trauma, but often one of tiredness or aching in the foot for some time before the onset of acute symptoms. The patient complains of pain, usually over the second or third metatarsal, rarely the fourth. First this causes him to rest the foot, and finally to seek advice. On examination the foot may be generally swollen, and there may be a visible or palpable swelling in the region of the



Fig. 707. Transverse fracture of the base of the fifth metatarsal.

shaft of the affected metatarsal. An X-ray reveals one of three conditions. (1) A little rarefaction of the shaft or neck of the affected metatarsal. (2) There is an oval shadow with a fracture of the metatarsal at its centre. (3) The shaft of the metatarsal is surrounded by a spindle-shaped shadow resembling callus, and no fracture is visible. The first is the early stage before fracture, accompanied by aching feet. The second is the established stage most commonly seen, in which fracture has followed changes in the bone. It is obvious that the pathology of the condition must have been in existence long before the radiograph was taken. The third stage is the healing stage, in which the fracture line has been obliterated by healing.



FIG. 708. Normal epiphysis at the base of the fifth metatarsal.

TREATMENT. This falls into two divisions, corresponding to the clinical severity of the case.

The Acute Case. Characterised by acute pain, sudden onset, swelling of the foot, and a recent fracture line in the X-ray. The foot should be elevated and rested for a few days, and as soon as the acute phase is over, treated as the subacute case.

The Subacute Case. The patient should be taken off heavy activity on the feet. A valgus insole with a sponge-rubber metatarsal pad should be provided. As a cheaper substitute a felt pad may be strapped under the metatarsal bases. Faradic foot baths and toe-stretching exercises are given and light activity in boots encouraged. The condition settles down in two to four weeks from the date of complaint under this régime.

Fracture of the base of the fifth metatarsal. This is due to sudden inversion of the foot, or blows on the outer aspect of the foot. It usually takes the form of a transverse fracture behind the

tuberosity of the bone, but smaller chips may be broken off the region of the tuberosity and interest attaches to them as they may be confused with any of the following conditions.

1. A normal epiphysis which unites at puberty (Fig. 708).
2. A persistent ununited epiphysis in an adult. (Rare.)
3. The os Vesalianum, a small vestigial remnant which lies opposite the tip of the bone.



FIG 709 Fracture of the tip of the base of the fifth metatarsal.

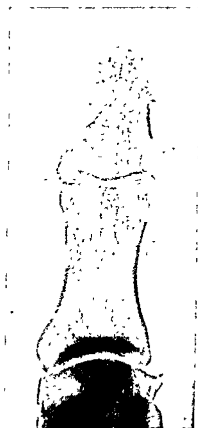


FIG. 710. Oblique fracture of the proximal phalanx of the great toe involving the joint.

4. Sesamoid bone in the region. (In tendon of peroneus longus) (Fig. 674.)

To differentiate these requires careful examination of the films and X-rays of the opposite side for comparison

The treatment of any fracture in this region is similar to that of a march fracture. In acute cases great relief of pain will follow infiltration of the fracture line with novocaine. This enables early massage and activity to remove œdema and swelling. Wearing a stiff-soled boot will be of assistance in relieving pain on walking in the later stages. Immobilisation in plaster is rarely required.

Fractures of the Phalanges of the Toes

The most commonly injured phalanx is the terminal phalanx of the great toe. As this is usually due to crushing injuries it is not infrequently compound, and accompanied by abrasions which makes strapping fixation impossible. Cases which to the casual glance do not appear compound are often indirectly compound below the nail. For this reason we believe in removing the nail in all serious crushing injuries of the toes and evacuating the hæmatoma. This relieves the patient of pain and cuts down the incidence of infection by removing a readily infected nidus and



FIG ... the extension ... netacarpal and ...

allowing the nail bed to dry up. Such a removal is followed by a light sole plaster bandaged to the foot, extending to just beyond the toes, and the resting of the leg on a Braun's splint, while the toe is exposed to radiant heat or the air. Under such circumstances the toes rapidly dry up and the patient can be given a walking boot or shoe with the toe-cap removed.

Non-compound fractures with little displacement can be supported by a few turns of strapping over a narrow pad of felt which comes well under the ball of the toe. This usually makes the toe susceptible to pressure from the shoe, and the most satisfactory method of getting over this is to cut the toe out of an old shoe and wear it till the swelling has gone, usually in two to three weeks' time. Further rest to the toe can be obtained if desired by incorporating a metal bar in the sole below the great toe.

Fractures of toes other than the great toe cause little disability as a rule, and require strapping only.

Fractures with displacement of any moment occur only in the

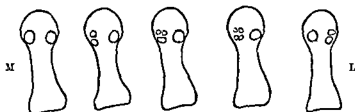


Fig. 712. The varieties of ossification of the sesamoids. M. Medial side. L. Lateral side.

proximal phalanx of the great toe, where any deformity is a disability. In the presence of abrasions skeletal traction must be employed by passing a stitch through the pulp of the toe, or the use of stainless

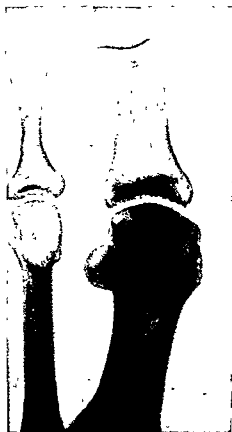


Fig. 713. Fracture of the medial sesamoid bone.

steel wire. This is attached to a wire incorporated in a leg plaster. In ordinary cases it will be sufficient to strap the toe to the wire and then bend the wire and toe as in the case of finger fractures.

The treatment of compound lesions has already been described,

elevation of the toes and absolute rest being important after excision and suture under local anæsthesia. The long disability which follows infected lesions of the toes makes every care worth while, and the condition itself is not without danger, Malgaigne in the pre-aseptic era having reported seven deaths in compound fracture of the great toe in a total of forty-one cases.

Fractures of the sesamoids of the great toe. These bones are rarely fractured, but are important as, if overlooked and untreated, long-continued pain in the foot may result. The only symptoms are pain in the foot which is localised to the sesamoid region, with some swelling and bruising in acute cases. They are recognised by the X-ray, but one may require an oblique view to establish a doubtful case, together with a view of the opposite side, as the sesamoids may ossify irregularly, and as this is invariably bilateral a comparative X-ray will rule out this condition. If unusual ossification has occurred it is the medial sesamoid which is most commonly involved. It may be divided into two, three or four sections. If the lateral sesamoid is involved it is divided into two only.

Treatment. In acute cases the foot must be rested in a walking plaster for three to four weeks in the hope of obtaining union. At the end of this time the plaster is removed and the patient given a metatarsal arch support. This is followed by a course of Faradic foot baths and exercises. In chronic cases the effect of a metatarsal arch support is first tried for a month, and if this fails to relieve the condition excision of the bone is advised.

FURTHER READING

Anatomy

Thurstan Holland. "The Accessory Bones of the Foot." Robert Jones Birthday Volume. Humphrey Milford, London, 1928. P. 157. (Also summarised in Lee McGregor's "Surgical Anatomy." John Wright.)

Talus

Smith, H. "Subastragaloid Dislocation," *J. Bone and Joint Surg.*, 1937, 19, 373.

Milch. "Astragalo-scaphoid Dislocation," *Ann. Surg.*, 1929, 89, 427.

Graham and Faulkner. "Astragalectomy for Fractures of the Astragalus," *Ann. Surg.*, 1929, 89, 435.

Bonnin, J. G. "Dislocations and Fracture Dislocations of the Talus," *Brit. J. Surg.*, 1940–41, 27, 88.

Coltart, W. D. "Aviators Astragalus," *J. Bone and Joint Surg.*, 1952, 34B, 545.

Bonnin, J. G. "Injuries to the Ankle," 1950. London, Wm. Heinemann (Medical Books) Ltd.

Calcaneus

CONN, H. R. "The Treatment of Fractures of the Os Calcis." (Method not recommended, but good bibliography), *J. Bone and Joint Surg.*, 1935, **17**, 392.

SCHOFIELD. "Fracture of the Os Calcis," *J. Bone and Joint Surg.*, 1936, **18**. 566.

HERMANN. "Conservative Therapy for Fracture of the Os Calcis," *J. Bone and Joint Surg.*, 1937, **19**, 709.

EASTWOOD. "Fracture of the Os Calcis," *Brit. J. Surg.*, 1938, **25**, 636. (Advocating conservative treatment.)

BROOMHEAD, HOSFORD and OTHERS. "Discussion on Fractures in the Region of the Ankle Joint," *Proc. Roy. Soc. Med.*, 1932, **25** (2), 1082.

PALMER, I. "The Mechanism and Treatment of Fractures of the Calcaneus." *J. Bone and Joint Surg.*, 1948, **30A**, 2–8.

WARRICK, C. K., and BREMNER, A. E. "Fractures of the Calcaneum." (With Atlas.) *J. Bone and Joint Surg.*, **35B**, 33.

Tarsus

WILSON, P. D. "Fractures and Dislocations of the Tarsal Bones," *South. M.J.*, 1933, **26**, 833.

Metatarsals

MEYERDING, H. W. "March Fracture," *Surg. Gynæ. and Obstets.*, 1938, **67**, 234.

IRWIN, G. "Fractures of the Metatarsals," *Proc. Roy. Soc. Med.*, 1938, **31**, 789.

DRUMMOND, R. "March Fracture, Report on a Case involving both Feet," *Brit. Med. J.*, 1940, **2**, 413.

CHAPTER XXXIV

DISLOCATIONS OF THE JAW AND UPPER EXTREMITY

Dislocations of the Mandible

DISLOCATIONS of the mandible may be unilateral or bilateral. Only the unilateral lesion arising from a blow on the side of the jaw is likely to be complicated by a fracture of the condyle or, less frequently, of other portions of the jaw. The bilateral lesion may occur spontaneously on yawning or on attempting a large bite. In full opening of the mouth the condyle slides forwards on to the eminentia articularis, and with slight further strain may slip over to the anterior aspect of this, and remain fixed there.



FIG. 714. Reduction of a dislocation of the mandible.

In bilateral lesions the jaw is fixed open, and the patient is unable to swallow, so he dribbles saliva. Depressions in front of both ears are palpable where the condyles normally lie. In unilateral lesions the jaw is not held so widely open, and the chin deviates to the uninjured side. Reduction in either case is usually readily brought about by grasping the lower jaw firmly in a towel, with the thumbs over the molars and the fingers outside. The jaw is first depressed and the whole mandible then pushed directly backwards. Reduction is nearly always possible without an anæsthetic. The after-treatment consists in the avoidance of gaping, the necessity for which is impressed on the patient by giving him a four-tailed bandage under the chin.

Fracture dislocations are often difficult to reduce, but in spite of failure to do so the movements of the jaw are quite good. If the condyle cannot be reduced by manipulation operative interference is unwise owing to the technical difficulties, and the poor results obtained do not justify it. Should a bad result be obtained from conservative treatment, and this is unusual, the condyle may always be excised later.

Dislocations of the Clavicle

The sterno-clavicular joint. The path of the dislocated medial end of the clavicle is insuperably resisted in one direction only, that downward and posterior, where it comes into collision with the first rib. It may pass in any other direction, but, owing to the strength of the articulation and of the costo-clavicular ligament, dislocation in any direction is rare. The injury is due to a fall on the point of the shoulder, or to direct violence (see Fig. 243).

Posterior dislocations. These are rare, and chiefly interesting because the pressure may deform the trachea and cause shortness of breath, or, if on the veins, cause venous engorgement of the arm.



FIG 715. Complete dislocation of the acromio-clavicular joint, indicating rupture of the conoid and trapezoid ligaments.

Upward dislocations. These are uncommon as the position is unstable, and the bone slips down to its normal position

Antero-inferiorly. This is the common lesion. The medial end of the bone appears to be very prominent and lies at a lower level than usual. A variable amount of bruising appears around the joint. The dislocation is readily reduced by any of the manœuvres which reduce a fractured clavicle, but it is difficult to retain in position. In practice this is unimportant as there is little disability if the bone is left in its abnormal position. An attempt to retain the position may be made by a pad over the medial end of the bone, held in place by a circular plaster applied over the injured shoulder and under the opposite axilla This is supplemented by a figure-eight bandage to draw the shoulder back. If successful this will have to be retained for three to four weeks. Operative reduction and fixation by fascial slings is most unsatisfactory.

The acromio-clavicular joint. This joint is not infrequently injured in falls on the shoulder, the lesion being either a sprain, a subluxation or a complete dislocation. With the sprain there is merely local pain. In the subluxation some increase in prominence of the injured clavicle will be palpable and may be shown in the X-ray. A small local chip or fissure fracture into the joint may be present. This lesion requires rest in Robert Jones' strapping for two to three weeks (see Fig. 256).

The more serious lesion is the complete dislocation of the joint, which can only occur when the conoid and trapezoid ligaments are torn. The whole weight of the limb then drags the acromion away



FIG. 716. Complete dislocation of the acromio-clavicular joint treated by a single screw into the acromion.

from the clavicle. The deformity is much more marked clinically than that due to subluxation, and an X-ray shows a wide separation of the joint surfaces. The treatment is similar to subluxation, for the aim is the same, the complete relief of the joint from the weight of the limb, but the immobilisation must be maintained much longer to give the damaged ligaments time to heal. A period of four to six weeks must elapse before this occurs and throughout this time care must be taken never to allow the support of the strapping to relax (see Chapter XIX)

The difficulties of retention with strapping demand continuous supervision and some stiffness of the elbow and shoulder may follow To avoid this open operation and fixation of the clavicle by a single screw passed through it into the coracoid process has been employed. The screw must not be fixed firmly in the clavicle or it will fracture with movement, and must have a washer to

prevent it pulling through the clavicle. After consolidation of the ligaments, it is removed, usually at the end of three months. Undoubtedly the best results are achieved by this method, but perfect function is possible with some deformity and it is not often carried out. In the rare cases in which pain persists at the acromio-clavicular joint excision of a $\frac{1}{2}$ inch of the end of the clavicle will give relief.



Fig. 717. Sub-glenoid dislocation of the humerus.

Persistence of pain after strain or subluxation or after the more serious lesion of dislocation may be considerably relieved, and in some cases abolished altogether, by the infiltration of the joint and ligaments with novocaine. In long-standing cases an oily solution such as "Proctocaine" may be employed as its effects last longer. Such treatment needs to be followed by immediate movements, assisted if possible through the full range, and a continuation of physiotherapy for two weeks.

Dislocations of the Shoulder

Stability is sacrificed in the shoulder joint to freedom of movement, and the price of this is the liability to dislocation, which makes *the shoulder the most frequently dislocated joint in the body.* The shallow glenoid cavity, the lax ligaments, and the long lever of the humerus all take a part in facilitating dislocation.

The causative violence may be direct or indirect, more commonly the latter, the usual accident being a fall on the extended abducted arm which levers the humerus against the acromion, and forces the



FIG. 718. Dislocation of the shoulder, showing the flattening of the shoulder and the abduction of the elbow. The grip on the wrist is a characteristic one to prevent pain from movement and is seen in many lesions of the shoulder and arm.

head of the humerus through the lower weak portion of the capsule. The head may remain there, but more commonly it is further displaced. In direct violence the head of the humerus is forcibly torn away from the glenoid, pushing the capsule off the bone. Such force may be transmitted from the elbow, or be due to a blow on the anterior or posterior aspect of the arm, especially if the elbow is fixed at the moment of impact. This type of injury is associated with fracture of the glenoid, or the tuberosities, or of the upper end of the humerus.

Dislocations may be classified according to their anatomical position :—

1. ANTERIOR. Sub-coracoid (see Figs. 265, 276).
   Sub-clavicular.

2. INFERIOR. Sub-glenoid. This is the primary lesion in most cases and is further displaced anteriorly or posteriorly (Fig. 717).
Luxatio erecta. In this rare lesion the head passes through the lower portion of the capsule, and the arm is then over-abducted, so that it slips down the axillary border of the scapula, and the arm remains fixed over the head.

3. POSTERIOR. Sub-acromial. } Both rare.
Sub-spinous. }

Dislocations may also be classified according to their frequency :—

1. ACUTE (NON-RECURRENT). The single dislocations described above.
2. RECURRENT. Following a dislocation the capsule may be torn and permanently weakened. This may permit recurrences with further injury. Characteristically the force re-*quired for each subsequent dislocation is* less, until the joint slips out for trivial reasons.
3. HABITUAL. With the passage of time the joint may slip out and in with simple movements and the patient become habituated to it, often developing a manœuvre to reduce it.

Congenital abnormalities around the shoulder or poliomyelitis may facilitate recurrent and habitual dislocations.

In all cases but luxatio erecta there are certain common physical signs.

1. Flattening of the normal deltoid contour (Fig. 718).
2. Inability to place the elbow against the side (Dugas' sign).
3. Prominence of the acromion with an unusual emptiness below it.
4. The head of the humerus may be felt to rotate under the fingers in an abnormal position
5. Hamilton's ruler test A ruler may be made to touch the *acromion and the lateral condyle of the humerus. Normally it is* prevented from this by the head of the humerus.
6. Increased diameter of the shoulder measured through the axilla, due to lowering of the axillary folds.
7. There is an alteration in the length of the arm.
8. There is a loss of mobility with a feeling well described as "elastic mobility" on trying to move the shoulder.

SUB-GLENOID DISLOCATION. In this lesion the length of the arm is increased. The head rests just below the glenoid and the anterior axillary fold is markedly lowered. It is the least stable of dislocations, and is usually readily reduced by direct traction on the arm.

SUB-CORACOID DISLOCATION. This is the most common *position* in which to find the head of the humerus. If still further displaced the rare sub-clavicular lesion may be produced. There is as a rule little detectable alteration in the length of the arm, but in full abduction it is shortened. The anterior margin of the capsule is frequently *separated at its* attachment to the glenoid, and such separation may lay the foundation for recurrent dislocations later on. Damage to vessels and nerves is uncommon.

Complications. INJURY TO THE SOFT PARTS. (*a*) *Axillary artery.* Pressure is uncommon and rupture very rare (Figs. 36, 37).



FIG. 719. Rupture of the short rotator cuff showing the rotation of the scapular in the attempt to obtain abduction. This sign is also found in subacromial bursitis (see p. 324).

(*b*) *Nerves. The axillary nerve is the most liable to damage,* from stretching or pressure. In rare instances traction on the brachial plexus may produce a lesion of the outer cord (C. 5 and 6). The *inner and middle cords* and the *ulnar, median and radial nerves* may suffer in unusual cases, the lesions being as a rule incomplete.

(*c*) *Tendons.* Rupture of the supra-spinatus tendon may occur with the development of the characteristic syndrome. Rupture of the subscapularis produces no characteristic disability, but increases the stiffness of the joint.

(*d*) Avulsion of the cuff of attachment of the short rotators of the humerus (see Fig. 272). This may be :—

COMPLETE. (*a*) *With dislocation.* Characteristically the shoulder re-dislocates almost immediately after reduction. Avulsed fragments of the tuberosities may be seen in the joint space. Early operation and fixation of the cuff to the humeral head is needed. A groove is cut in the anatomical neck and the fibrous cuff sewn to the bone by plaited steel wire sutures. The shoulder is maintained in abduction for two to three weeks afterwards and gradually brought to the side.



FIG 720 Kocher's manœuvre.
(a) Stage of traction.

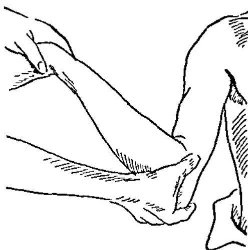


FIG. 721. Kocher's manœuvre.
(b) Stage of external rotation.



FIG. 722. Kocher's manœuvre
(c) Stage of adduction of the elbow.



FIG. 723. Kocher's manœuvre.
(d) Stage of internal rotation.

(b) *Without dislocation.* The signs have been detailed on page 325. The appearances of bruising around the borders of the deltoid and the typical loss of power to start abduction are characteristic. This has to be considered in the differential diagnosis of shoulder injuries.

INCOMPLETE. This was described once as rupture of the supraspinatus. Inspection of many injuries has shown that the lesion is not always confined to this tendon. A variable degree of power to abduct may be retained or return quickly. As the results of operation are not entirely satisfactory, and reasonable spontaneous recovery may occur a waiting policy may be adopted. Only if there is insufficient recovery is operation advised. This should be adequate by the end of the second week for there to be a reasonable chance of success without operative repair.

(c) *Subacromial bursa.* Adhesions and partial ruptures of the short rotators lying in its floor are productive of much stiffness (see p. 324).

INJURY TO THE BONES (see Fracture Dislocations, Chapter XXI).

Treatment. Reduction as soon as possible is the first aim. Not only does this relieve the patient from pain, but there is a period immediately after the injury in which there appears to be a mild anæsthesia, and consequently less muscle spasm, and in which reduction without an anæsthetic is considerably easier.

METHODS. Now that muscle spasm can be so easily abolished for the short time necessary for reduction by intravenous anæsthesia this should always be used if available. When relaxed the head of the humerus will often slip back easily by gentle traction on the fixed elbow and slight outward pressure on the head from a hand in the axilla. Failing this Hippocratic or the Kocher's method is used.

1. *Hippocratic method.* If the above method fails, and under anæsthesia this is seldom the case, traction is applied to the arm. This may be carried out with the arm in various positions : (1) the arm may be slowly brought above the head and almost vertical traction be applied. (2) The arm may be pulled upon when at right angles to the body with a counter-traction band around the chest. (3) In the classical Hippocratic method the unbooted heel is placed in the axilla for counter-traction, and is used as a fulcrum after a short period of traction by adducting the arm over it.

Often the use of the closed fist in the axilla is sufficient, with traction applied to the bent elbow with the opposite hand. Manœuvre exerts considerable force, and care must be taken not to convert a dislocation into a fracture dislocation.

2. *Kocher's.* This method aims at making the head of the humerus retrace its path, and is most suitable for sub-coracoid dislocations. Though probably based on incorrect anatomical considerations, it is nevertheless effective. In many cases it can be

carried out slowly and gently without anæsthesia. Whenever difficulty is encountered the first step to overcome it is general anæsthesia to abolish muscular spasm.

(*a*) For a short period traction is applied to the arm in the slightly flexed and abducted position.

(*b*) The patient's forearm is then used as a lever and with the elbow steadied at the side the humerus is slowly fully externally rotated. It is this proceeding which should be done slowly and steadily, as it tenses the untorn subscapularis.

(*c*) The elbow is now adducted across the chest while the external rotation is maintained.

(*d*) Finally, with the elbow still steadied, the arm is internally rotated by sweeping the hand across the face to the opposite shoulder. It is during this movement that reduction usually occurs.

Both these methods if carelessly applied are dangerous and may do damage to the brachial plexus. For this reason they should be used only after the gentler methods have failed, and with deep anæsthesia and a muscle relaxant it is unusual for them to fail. The importance of a neurological examination before reduction should not have to be emphasised if the discovery of a lesion after reduction is not to be attributed to the manipulation.

After-treatment. The arm is kept in a sling for three weeks, exercises, massage and movements being commenced at the end of the first week. In these movements full abduction is avoided, but external and internal rotation insisted upon. It is found that an arm capable of full internal and external rotation is capable of almost full abduction.

LONG-STANDING CASES. After a short time there is shortening and contraction of muscles which makes reduction difficult and, if forced, dangerous. No exact period as to the date after which reduction is impossible can be given, but after the fourth week efforts to reduce the dislocation are not likely to succeed Under these circumstances it is necessary to submit the case to operative reduction through an anterior incision, which may be a difficult procedure, and may end up with an excision of the head of the humerus. It is often remarkable how good is the function of an unreduced dislocation, and such cases are certainly better left in the elderly.

Posterior dislocations of the shoulder. These are uncommon, but notoriously difficult, owing to the fact that the overlap of the glenoid by the head of the humerus is slight, and careless inspection of the antero-posterior radiograph give the impression that no dislocation exists (Fig 724). The physical signs are, however, so characteristic that there is little excuse for failure to take a lateral film with the arm abducted (for which in some cases an anæsthetic may be needed) which shows the characteristic displacement (Fig. 725).



FIG. 724. Posterior dislocation of the shoulder, showing the slight difference from the normal, namely slight glenoid over-lap and unusual rotation of the head.



FIG. 725. The characteristic appearance in the lateral film.

CLINICAL SIGNS. Swelling may obscure the posteriorly displaced head (Fig. 726), but this is often readily palpable, or becomes so in a few days The shoulder is held elevated, the depression over the acromio-clavicular joint is lost, and the whole shoulder assumes an eliptical and less rectangular form (Fig. 727) The most outstanding sign is the complete inability to externally rotate the arm, which is almost fixed in internal rotation, especially if there is an anterior groove on the head, which catches in the glenoid (Fig. 728). This is comparable to the posterior groove in anterior dislocations



FIG. 726. Lateral view of a posterior dislocation showing the bulge of the posteriorly displaced head.

TREATMENT. Reduction is as a rule simple when relaxation has been produced by anæsthesia. A few cases with minimal capsular damage, and no groove on the humeral head, will prove to be stable. Others, and probably the majority, will recur as soon as the arm is either internally rotated or adducted. The reduction is stable in abduction and external rotation, as this engages the broader, undamaged part of the humeral head with the glenoid. The patient should be nursed in this position in a simple abduction frame (Fig. 152) for two to three weeks when the arm may be slowly

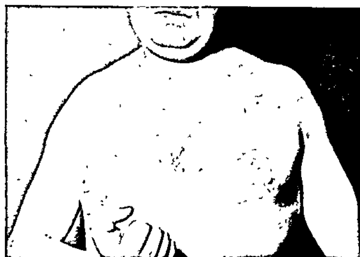


FIG. 727. The front view of a posterior dislocation of the shoulder, showing well the altered contours. The patient is endeavouring to externally rotate both arms, the right is almost fixed against the chest.

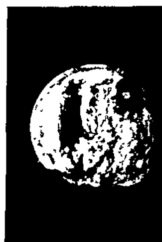


FIG. 728. A photograph of a left humeral head removed at operation after posterior dislocation showing the groove on the anterior surface of the head.

brought to the side without the dislocation recurring. Check lateral films, are of course necessary from time to time to check the maintenance of reduction. Even after a late discovery of the dislocation, *e g.*, after a month, this régime will prove successful.

Dislocation of the Elbow

The elbow follows the shoulder in order of frequency of dislocation, but while in shoulder lesions the patient is usually adult, in elbow dislocations a high percentage occur in children and adolescents owing to the undeveloped state of the coronoid and olecranon processes.

Dislocations may be :—

1. Posterior. The most common lesion.
2. Anterior. A rare lesion, accompanied by olecranon fracture.

3. Lateral or medial.

4. Divergent dislocations in which the upper radio-ulnar joint is also dislocated.

5. Dislocations of the head of the radius alone.

POSTERIOR DISLOCATIONS. These occur from falls on the hand in which the force, had it been transmitted more directly to the humerus, would produce a supra-condylar or shaft fracture. The



Fig. 729. Posterior dislocation of the elbow, showing posterior displacement of the head of the radius.



Fig. 730. Lateral view of a posterior dislocation *of the elbow.*



Fig. 731. Posterior view of the same case to show the broadening of the elbow.

TREATMENT. Reduction is as a rule simple when relaxation has been produced by anæsthesia. A few cases with minimal capsular damage, and no groove on the humeral head, will prove to be stable. Others, and probably the majority, will recur as soon as the arm is either internally rotated or adducted. The reduction is stable in abduction and external rotation, as this engages the broader, undamaged part of the humeral head with the glenoid. The patient should be nursed in this position in a simple abduction frame (Fig 152) for two to three weeks when the arm may be slowly

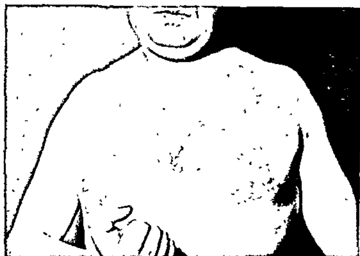


FIG. 727. The front view of a posterior dislocation of the shoulder, showing well the altered contours. The patient is endeavouring to externally rotate both arms ; the right is almost fixed against the chest.



FIG 728 *A photograph of* a left humeral head removed at operation after posterior dislocation showing the groove on the anterior surface of the head.

brought to the side without the dislocation recurring. Check lateral films, are of course necessary from time to time to check the maintenance of reduction. Even after a late discovery of the dislocation, *e.g* , after a month, this régime will prove successful.

Dislocation of the Elbow

The elbow follows the shoulder in order of frequency of dislocation, but while in shoulder lesions the patient is usually adult, in elbow dislocations a high percentage occur in children and adolescents owing to the undeveloped state of the coronoid and olecranon processes.

Dislocations may be .—

1. Posterior. The most common lesion.
2. Anterior. A rare lesion, accompanied by olecranon fracture.

The rapid onset of swelling in the elbow may obscure the diagnosis, and is an added reason for early reduction.

TREATMENT. This consists of early reduction which is usually simple and carried out by the method outlined in Chapter XXI for the reduction of flexion fractures of the humerus. The manipulations with the fingers will obviously differ, but the grip recommended gives the best control. After traction with the elbow bent the humerus is pushed back with the thumbs, and readily slips into the sigmoid notch.

After-treatment. The elbow is retained in a cuff and collar or high sling in moderate flexion for three weeks and then transferred to a low sling. The patient is then encouraged to move his elbow to the full extent allowed by the sling for a week, and it is then dispensed with. The return of movement to the elbow is left to the action of the musculature of the arm, and all forced movements, weight carrying and the like are forbidden. Gentle and persistent active exercises are encouraged. Full movement is usually restored in six weeks. The treatment of dislocation complicated by fracture is the treatment of the fracture after the dislocation has been reduced.

OTHER DISLOCATIONS OF THE ELBOW. In the rarer lesions the displacement is usually obvious, and should be confirmed by an X-ray. In anterior dislocations there is usually an associated fracture of the olecranon.

Medial dislocation may involve the ulna alone if the orbicular ligament is detached, but usually the two bones move together. The sigmoid notch rests on the edge of the epicondyle, and is readily returned to normal position by extension on the flexed elbow and medial pressure.

Lateral dislocation may be accompanied by tearing of the orbicular ligament and dislocation of the head of the radius. It is interesting as it is the probable mechanism of fracture of the medial epicondyle with displacement into the joint (see Chapter XXI). In many of these cases the displacement is incomplete or spontaneously reduced and the position of the displaced fragment may be



FIG. 733. Lateral dislocation of the elbow showing anterior dislocation of the head of the radius. The same case as in Fig. 734.

head of the radius moves with the ulna, owing to the annular ligament being intact. Fracture of the coronoid may occur, and the brachialis anticus is always separated to some extent, which may lead to some calcification in it later on.

Diagnosis. The appearance of the arm if not obscured by swelling is typical. The patient holds the forearm by the wrist in incomplete extension (135°). The elbow appears broadened from behind, and the forearm is shortened. There is a hollow above



FIG. 732. Medial dislocation of both bones of the forearm. Intact upper radio-ulnar joint.

the olecranon, which may give the humerus the appearance of being bowed backwards A valgus or varus deformity may be associated. Pronation and supination is partly lost It is distinguished from a fracture of the humerus by the features described and by the alteration in the normal relationship of the olecranon to the epicondyles (see p. 331) An X-ray must be taken in all cases to determine the associated bony injury, which may be :—

1. Fracture of the head of the radius
2. Fracture of the coronoid process.
3. Fractures of the capitellar surface of the humerus
4. Fracture of the medial epicondyle (see Figs. 309, 310)
5. Other more extensive fractures of the lower end of the humerus.

deformity due to displacement of the head of the radius which can be felt to rotate in an abnormal position, and loss of mobility. In the case of anterior dislocations flexion is very limited. The loss of the supporting action of the radius allows abnormal abduction at the elbow.

TREATMENT. Reduction is made by traction on the extended and adducted elbow, while local pressure is made over the displaced head in the required direction. As soon as it is felt to flick back in front of the capitellum the elbow is flexed and supinated. If this movement cannot be carried out the reduction is not complete. If complete the elbow is immobilised in this position with a posterior slab and sling.

Two complications are met with in this group of cases. Firstly, cases which are easy to reduce but difficult to retain, and, secondly, cases in which manipulative reduction is impossible. In the first group the head of the radius can usually be controlled by adequate flexion, but if this fails at the end of several attempts operation must be carried out. Failure of reduction is due to the interposition of soft tissues, usually the orbicular ligament. Retention is simple once the obstruction is overcome. The second group of cases shows no very obvious reason for the failure of reduction, but an X-ray will usually reveal a lower radio-ulnar subluxation, with the lower end of the radius caught in the lower margin of the ulna. This can only be released by section of the posterior ligament of the joint, which can be done with a tenotomy knife after which the head of the radius fits back into place.

An interesting and related lesion is " pulled elbow," a condition met with in children from two to six years of age after sudden traction on the forearm. The child complains of pain in the elbow, refuses to use it, and holds it in pronation. On examination, flexion and extension will be found to be free, but supination is limited. The X-ray is usually negative. The theory of its ætiology is that the cartilaginous head of the radius is pulled through the orbicular ligament which closes down between the head of the radius and the capitellum. The treatment is forced supination which produces a slight click and full restoration of movement. This may sometimes be managed without anæsthesia.

Dislocation of the lower radio-ulnar joint. This is an unusual lesion occurring alone, when it arises from direct violence, but it is not uncommonly associated with other lesions : (1) fracture of the shaft of the radius in the lower third (see Figs. 333, 334) ; (2) severe Colles's fractures ; (3) dislocation of the head of the radius.

Fracture of the shaft of the radius alone is not difficult to treat in the absence of dislocation at the lower radio-ulnar joint, though one



Fig. 734. Lateral dislocation of the elbow. The cross on the skin lies over the olecranon. The X-ray of this case is shown in Fig. 733.

overlooked If the displacement is noted before the dislocation is reduced an attempt may be made to keep it out of the joint by pulling on the bellies of the extensor muscles as the dislocation is reduced.

An X-ray is taken after reduction and if the epicondyle is still in the joint it is removed by open operation.

Divergent dislocation In this lesion the shaft of the humerus is forced between the two bones of the forearm with resultant tearing of all the ligaments of the joint. The ulna slips up posteriorly and the head of the radius to the lateral side so that the forearm becomes locked in almost complete extension Reduction is carried out by extension in the line of the arm till the sigmoid notch is engaged, and then flexion of the elbow while the head of the radius is forced down by pressure. The arm is then immobilised in moderate flexion by a posterior plaster gutter splint The after-treatment is that of other dislocations of the elbow.

Dislocation of the head of the radius alone For this to occur the orbicular ligament must be ruptured. The head may then pass anteriorly, posteriorly, medially or laterally, and during any of these movements the deep branch of the radial nerve is likely to be injured. If the head of the radius is displaced to any extent associated injuries are usually present.

1. Fracture of the ulna. (Monteggia fracture, see Chapter XXIII).
2. Fracture of the radius
3. Dislocation at the lower radio-ulnar joint.



Fig 735 Medial dislocation of the head of the radius An unusual case with damage to both median and ulnar nerves, the radial nerve escaping damage Operative reduction is necessary in such a case.

The symptoms consist of pain and local bruising and swelling,



FIG. 736. Dislocation of the first carpo-metacarpal joint. Lateral view.



FIG. 737. A.P. view of the same case.



FIG. 738. Lateral dislocation at an inter-phalangeal joint.



FIG. 739. Posterior dislocation of the terminal phalanx of the thumb.

may require skeletal traction to obtain correct apposition. When the joint is dislocated, however, the lesion is very unstable, and the radius tends to displace toward the ulna and the hand to pass into radial deviation.

This tendency to deviate may be resisted by several methods.

(*a*) The hand may be splinted in ulnar deviation and traction placed on the thumb. This is not advised as the traction is likely to leave a stiff thumb.

(*b*) After reduction by skeletal traction a wire may be passed through the radius and ulna below the fracture to hold it in the correct position and incorporated in the plaster.

(*c*) The fracture may be fixed by open operation, and screwing or plating (Fig. 336).

After reduction careful control X-rays are necessary at short intervals to check recurrence of the deformity, and the arm must be replastered as swelling subsides. If mal-union occurs the condition can be very crippling. Operative fixation will be found to give the most satisfactory results.

Subluxation and dislocation of the joint should be watched for particularly in comminuted fractures of the Colles's type. Accurate lateral X-rays are important in this connection as small degrees of displacement can be obscured by an oblique film. The reduction of the fracture reduces the dislocation as a rule, but there is likely to be excessive mobility of the lower end of the ulna as a sequel. This produces little disability.

Dislocations of the wrist. This, together with fracture dislocations, has been discussed in Chapter XXIV.

Carpo-Metacarpal

Metacarpo-phalangeal and Inter-phalangeal Dislocations

Dislocations at the metacarpo-phalangeal and inter-phalangeal joints are readily reduced by traction. Those affecting the thumb are the most interesting The fracture dislocation of the metacarpo-carpal joint of the thumb has already been discussed (Chapter XXV). In dislocation without fracture the symptoms, diagnosis and treatment are similar, and the condition can only be detected with certainty by an X-ray. Once reduced the condition is much more stable than a Bennett's stave fracture, and the strapping method of fixation suffices to retain it

Of the metacarpo-phalangeal dislocations only that of posterior dislocation of the thumb is of particular interest, as in these cases one may meet with unexpected resistance to reduction. The condition arises from excessive strain on the abducted thumb and



FIG. 741. Posterior dislocation of all four metacarpo-phalangeal joints of the palm—compound into palm.



FIG. 742. X-ray appearance of previous case.

the base of the phalanx becomes pulled dorsally over the head so that the two bones are almost at right angles. Traction accompanied by flexion reduces the lesion in many cases, but in a certain number the anterior aspect of the joint is buttonholed around the head of the metacarpal, and attempts to reduce the dislocation only increase the tightness of the grip of the tissues. Such cases should be submitted to open operation through an antero-lateral incision. After partial division of the tense bands and judicious levering the dislocation may be reduced. It is then put up on a padded finger splint, flexed. At the end of a fortnight strapping is substituted for the wire splint. In four weeks' time the joint is stable and moderately freely movable. If manipulative reduction has been successful it is sufficient to strap the thumb with several turns of figure-eight strapping.



Fig. 740. Padded wire finger splint applied on the flexor aspect of the thumb for an inter-phalangeal dislocation.

Metacarpo-phalangeal dislocations of the fingers are usually dorsal and are readily reduced by traction and pressure. The use of a flexed padded wire finger splint is much more satisfactory than flexion of the fingers over a bandage, as the movement of one finger only is restricted by it (see Fig 48).

A compound dislocation at all four metacarpo-phalangeal joints is shown in Figs. 741, 742 This occurs occasionally from forced hyperextension of all four fingers Reduction after adequate wound toilet is easy and stable. Finger movements are commenced at the end of the first week.

Inter-phalangeal dislocations. Th [illegible]
fractures which have been described [illegible]
X-ray is advisable to exclude them. [illegible]
dorsal or volar or lateral The diagnosis is obvious and reduction is straightforward The finger is rested on a padded finger wire splint for a week, and then strapping is substituted.

Carpo-metacarpal dislocations. These are seldom complete, either the fourth and fifth metacarpal being separated from the hamate, or the first and second from the capitate, trapezium and trapezoid. [illegible] by pressure Subluxations with pain and swelling [illegible]
light use. [illegible]
second metacarpal accompany subluxation.

CHAPTER XXXV

DISLOCATIONS OF THE LOWER EXTREMITY

Dislocations of the Sacro-iliac Joint and Pubic Symphysis

Very rarely there may be a separation of both joints together with a complete dislocation of one half of the pelvis. More commonly either the *sacro-iliac joint or the pubic symphysis is* injured in association with a fracture of some other part of the pelvic ring (p. 442). This produces the same displacement, is treated in the same manner and liable to the same complications as double fractures of the pelvis, which are described in Chapter XXVI.

Dislocations of the coccyx. This lesion is readily reduced by a finger in the rectum. Early abdominal breathing exercises and radiant heat are advisable to avoid persistent pain. Novocaine injection may be of value.

Dislocations of the Hip

Compared with dislocations of the humerus, dislocations of the hip are only one-tenth as common.

The posterior type of dislocation is not infrequently associated with fractures of the acetabular rim, particularly when the femur is driven backwards against the deepest part of the socket. The most serious type of fracture accompanies central dislocation of the hip, when the head of the femur is driven through the floor of the acetabulum, a condition described in Chapter XXVI.

Types of dislocation of the hip.

1. Posterior. (*a*) Iliac. } Associated with fracture of the
   (*b*) Sciatic. } acetabular rim (Fig. 743).
2. Anterior. (*a*) Pubic.
   (*b*) Obturator.
3. Central (see p. 452). Associated with fractures of the acetabular floor.

Posterior dislocations. Violence applied to the leg in the position of flexion, adduction and internal rotation forces the head of the femur against the lower posterior portion of the capsule. This is the weakest area, and if the force is sufficient it tears the capsule and drives the femoral head on to the surface of the iliac bone (*iliac dislocation*). In cases in which the body is more flexed on the thighs at the moment of impact, the head passes downward towards the great sciatic notch, the so-called *sciatic dislocation*. Here the sciatic nerve is liable to injury. Such violence typically occurs when a

FURTHER READING

Shoulder

BANKART, A. S. B. "Dislocations of the Shoulder Joint," Robert Jones Birthday Volume. Oxford : Medical Publications, 1928, p. 307.

BOSWORTH, D. M. "Shoulder Lesions," *J. Bone and Joint Surg.*, 1940, 22, 369.

NICOLA, T. "Acute Anterior Dislocations of the Shoulder," *J. Bone and Joint Surg.*, 1949, 31A, 153.

WILSON, J., and MCKEEVER, F. M. "Traumatic Posterior Dislocation of the Humerus," *J. Bone and Joint Surg.*, 1949, 31A, 153.

TOWNLEY, C. O. "Recurrent Dislocation of the Shoulder," *J. Bone and Joint Surg.*, 1950, 32A, 370.

NASH. "The Status of Kocher's Method of Reducing Recent Anterior Dislocation of the Shoulder," *J. Bone and Joint Surg.*, 1934, 16, 535. (An article criticising justly Kocher's method on anatomical grounds. With full bibliography.)

REICH, R. "Traumatic Dislocation of the Shoulder," *J. Bone and Joint Surg.*, 1932, 14, 73.

VARIOUS AUTHORS. "Recurrent Dislocation of the Shoulder," *J. Bone and Joint Surg.*, 1948, 30B, 9–48.

Elbow

COHN. "Forward Dislocation of Both Bones of the Forearm at the Elbow," *Surg. Gynæ. and Obstets.*, 1922, 35, 776.

GEIST and HENRY. "Dislocations and Simple Fractures of the Elbow," *Minnesota Med.*, 1928, 11, 509.

WILSON. "Fractures and Dislocations in the Region of the Elbow," *Surg. Gynæ. and Obstets.*, 1933, 56, 335. (Long and complete article.)

Acromio-clavicular and Sterno-clavicular Joints

HENRY, M. O. "Acromio-Clavicular Dislocations," *Minnesota Med.*, 1929, 12, 431.

NIESSEN, H. "Zur Behandlung der Retrosternalen Luxation der Clavicula," *Deutsche Ztschr. f. Chir.*, 1930, 231, 405.

TRYNIN, A. H. "Treatment of Fractures of the Outer End of the Clavicle," *Surg. Gynæ. and Obstets.*, 1933, 57, 118. (Recommends the use of the Bohler clavicle splint.)

TRYNIN, A. H. "Dislocation of the Acromio-clavicular Joint," *J. Bone and Joint Surg.*, 1932, 14, 421.

Carpo-metacarpal Joints

WAUGH, R. L., and YANCEY, A. G. "Carpo-Metacarpal Dislocations," *J. Bone and Joint Surg.*, 1948, 30A, 397.

Bigelow's method of circumduction is the last resort. The patient is placed on the floor, and the pelvis steadied in a similar



FIG. 744. The reduction of a posterior dislocation of the hip by Stimson's method.



FIG 745. The reduction of a posterior dislocation of the hip by traction and lifting the head forward.

manner. With the knee flexed the surgeon flexes the hip on the abdomen to a small degree and places traction on the femur by pulling on the bent knee. After a few minutes' traction to relax

passenger sitting in a car with his legs crossed is thrown forward against the dashboard and strikes it with his knee, when the car is brought to a sudden standstill.

Whether the dislocation is sciatic or iliac, the clinical signs are much the same. There is loss of hip movement, and the leg is held flexed, adducted and internally rotated. This position is maintained owing to the pull of the unruptured Y-shaped ligament. The great trochanter is more prominent, and the whole buttock appears larger. Comparative measurement of the limb is impossible owing to its *flexed position.* On attempted movement of the hip "elastic rigidity" is encountered and unless there is an associated fracture there is no crepitus In thin subjects the head may be palpated in an abnormal position.



FIG 743. Posterior dislocation of the hip together with undisplaced fracture of the posterior margin of the acetabulum.

TREATMENT. This consists of immediate reduction. The simplest method is that of Stimson, in which the patient is placed face downward on an operating couch, so that the legs hang over the end sufficiently to allow the injured hip *to flex to a right angle. The uninjured leg is steadied by an* assistant. The foot of the injured leg is grasped between the surgeon's knees, and one hand is used to make downward pressure behind the knee, while the other on the buttock follows the course of the reduction. By this method gravity is used to aid in the reduction.

The more commonly used modification of this method is that with the patient lying on his back on the floor and the pelvis steadied by an assistant. The surgeon then attempts to lift the head of the femur forward with the leg in a neutral position.

Bigelow's method of circumduction is the last resort. The patient is placed on the floor, and the pelvis steadied in a similar



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the muscles the limb is then abducted, externally rotated, and finally circumducted outwards, to be brought down beside the other limb with a sweeping movement.

After-treatment. This is divided into two schools of thought, those who on account of the comparative stability of the reduced joint commence early exercises, and those who, taking into account the severity of the injury necessary to produce such a lesion and the possible complications, prefer immobilisation in plaster. Taking all points into consideration it would appear that a fortnight's rest in bed, followed by a short walking hip spica of the type applied for abduction fractures of the head of the femur worn for a further three to five weeks, provides satisfactory care with the maximum freedom.



FIG. 746. Formation of a false acetabulum after an unreduced posterior dislocation of the hip. The occurrence of a dislocation was missed owing to shortening of the limb on the opposite side from a fracture.

COMPLICATIONS. 1. *Fracture of the acetabular rim.* If a large portion is separated this may make the dislocation unstable, and after reduction a period of traction is necessary, or open operation and the pegging of a large fragment (see Chapter XXVI). More commonly only a small chip is displaced and can be neglected (Fig. 743).

2. *Avascular necrosis of the head of the femur.* This is of rare occurrence. Strangely enough, it is of more common occurrence in dislocations in the young and adolescent, due to the greater violence necessary to produce a dislocation (Fig. 516). Careful watch for its occurrence is necessary, the hip meantime being relieved of weight bearing. Slow absorption of the head and replacement will occur but degenerative arthritis follows. In children Perthes' disease has sometimes followed dislocation and has been ascribed to vascular interference, but the evidence is not yet completely convincing.

3. *Sciatic nerve pressure.* This only occurs in posterior dislocations. It is usually bruising producing an incomplete lesion, and recovers rapidly

4. *Myositis ossificans.* This may occur around the hip, especially if the dislocation is accompanied by a fracture. The usual precautions to prevent this occurrence must be taken (see Chapter VI).

5. *Fracture of the femur.* Associated injuries to the femur are rare, but the head, neck or shaft may be fractured. Occasionally the neck of the femur

is fractured during manipulations to reduce a dislocation. In these cases the head is so grossly displaced that its blood supply is almost invariably damaged, and this is still further damaged by operative reduction, so that we are left almost only one alternative, excision of the head of the bone and insertion



Fig. 747. Anterior dislocation of the hip. Obturator type.

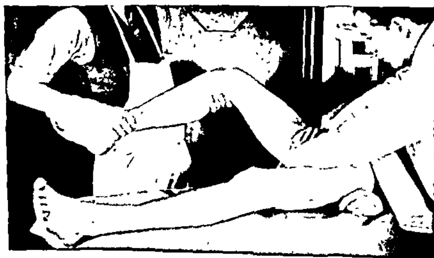


Fig. 748. The reduction of an anterior dislocation of the hip by traction and pressure over the upper end of the femoral shaft in a downward and outward direction.

of a prosthesis of the Judet type: a preference can be reasonably expressed for the metallic types, which are less liable to break. Where a fragment of the head lies loose in the joint it must be removed. This may often be combined with a posterior approach to fix a fragment of the acetabular rim, against which the fragment has been sheared off. Dislocations associated with fracture of the shaft can best be reduced by Stimson's method, or the shaft may be transfixed with a pin for control.

6. *Failure to reduce the dislocation* may not be shown on the antero-posterior film if the position of the head coincides with the acetabular shadow. For this reason a lateral X-ray is advisable. If left unreduced for some time a false acetabulum may form and reduction become impossible. The new acetabulum may be deceptively like the real one and be overlooked in the antero-posterior film (*Fig. 746*).

Anterior dislocations. These are produced by violence applied to the limb in abduction, the neck of the femur levering on the rim of the acetabulum and forcing the head of the femur out anteriorly. Such injuries are less frequent than those producing posterior dislocations. The Y-shaped ligament remains intact and holds the leg in the characteristic position of abduction, slight flexion and external rotation The adductors and obturator internus are usually torn, and the head comes to rest on the obturator externus or the pubic bone. The head of the femur is easily palpated in this position. The limb appears to be lengthened more than it actually is, the true lengthening being about 1 inch.

TREATMENT. Reduction is carried out by one of the following methods:—

1. *Traction* The patient is placed on a table and the hip flexed to 45° and abducted. Traction is applied in this position, and the return of the head to the acetabulum is assisted by downward and outward pressure over the adductors. Internal rotation and adduction then slips the head into the socket

2. *Bigelow's manœuvre.* This is a similar method of circumduction to that used in posterior dislocations. The leg in this case is flexed, externally rotated, and then circumducted inward, being finally extended.

After-treatment. This is as for posterior dislocations.

Complications are similar except that the femoral artery is liable to damage in place of the sciatic nerve, and there is no tendency to fracture the acetabular rim.

Dislocations of the Knee

The knee relies for its strength on the ligamentous and muscular attachments surrounding it. It is very rarely completely dislocated, owing to the large area of its almost flat articular surfaces which demands great displacement. More frequently a subluxation occurs,

with tearing of one or other of the ligaments, and these conditions are important as they may pass unrecognised at first.

Dislocation may be :—

ANTERIOR. Due to forced hyper-extension, or blows on the upper end of the tibia behind the flexed knee.

POSTERIOR. Due to direct violence applied in a backward direction to the head of the tibia, usually with the knee flexed.

LATERAL. Due to a combination of abduction and adduction strain with direct violence.



FIG. 749. Anterior dislocation of the knee.

The diagnosis in all cases of complete dislocation is obvious. The lesion may be compound. In posterior dislocation there may be pressure on the popliteal artery. Reduction is easy owing to the complete ligamentous tearing, when muscle spasm has been abolished by general anæsthesia. After reduction the knee is aspirated and a pressure bandage applied, and the leg rested on a straight Thomas splint for ten to fourteen days. At the end of this period a long walking plaster stretching from the groin to the toes is put on, with the knee in 10° of flexion. Weight bearing is permitted in this in three to four weeks. At the end of eight weeks the foot is allowed to remain free, a knee fixation plaster as used for fractures of the patella being applied. This plaster is persisted in until a stable knee results, which may take four to six months. At the end of this period free movements are allowed. The disability is often not as gross as might be expected, but a permanently unstable knee may demand the support of a knee cage.

Injuries to the individual ligaments. Unless one is on the look-out for these they may pass unobserved, especially if no X-ray is taken with the ligament on the stretch.

of a prosthesis of the Judet type : a preference can be reasonably expressed for the metallic types, which are less liable to break. Where a fragment of the head lies loose in the joint it must be removed. This may often be combined with a posterior approach to fix a fragment of the acetabular rim, against which the fragment has been sheared off. Dislocations associated with fracture of the shaft can best be reduced by Stimson's method, or the shaft may be transfixed with a pin for control.

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Complications are similar except that the femoral artery is liable to damage in place of the sciatic nerve, and there is no tendency to fracture the acetabular rim.

Dislocations of the Knee

The knee relies for its strength on the ligamentous and muscular attachments surrounding it. It is very rarely completely dislocated, owing to the large area of its almost flat articular surfaces which demands great displacement. More frequently a subluxation occurs,

3. THE MEDIAL COLLATERAL LIGAMENT. This occurs from forced abduction of the leg such as may occur in being struck on the outside of the leg by the bumpers of a car, or in the collapse of a narrow trench on a workman. It is distinguished from a strain of the ligament by the size of the ecchymosis, the increased pain, the effusion into the knee joint, and characteristically by the ability to abduct the tibia on the femur. If an X-ray is taken and there is no ligament traction fracture present, the film may appear



FIG. 751. Rupture of the medial collateral ligament of the knee. An X-ray must be taken with the knee in forced abduction to show this.

normal. Re-X-ray with some attempt to abduct the leg at the knee will show an increased width of the joint space on the medial side of the knee, thus giving the correct diagnosis. After such an accident, and possibly after repeated minor trauma, ossification may be met with in the base of the ligament, Pellegrini Steida's disease. This is due to degenerative change in the damaged ligament, followed by metaplasia, and not to periosteal tearing with callus formation.

4. THE FIBULAR COLLATERAL LIGAMENT. This is torn as the result of severe adduction strain, which is less common than

It is therefore prudent to aspirate any knee in which there is any gross effusion. If it is at all heavily bloodstained and no fracture has been found to account for this, a ligamentous injury is certain. Adequate clinical examination cannot be carried out on account of muscle spasm and pain, and examination under intravenous anæsthesia is essential. This should be combined with radiological examination with the suspected ligament under strain.

1. The anterior cruciate ligament. This runs from the medial surface of the outer condyle of the femur to the anterior tibial spine, and is tightened by extension. It can consequently be ruptured by hyper-extension or any forward displacement of the tibial plateau. Rupture of the ligament allows excessive forward mobility of the knee joint (see Fig. 568).

2. The posterior cruciate ligament. This runs from the *lateral face and anterior aspect of the medial condyle backwards and* outwards to the posterior tibial spine. It is tense in flexion and is injured by the same direct violence to the tibia with the knee flexed, which produces posterior dislocation of the knee. If it is ruptured excessive backward mobility of the tibia on the femur is permitted.

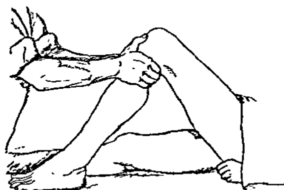


Fig. 750. Testing the knee for rupture of the cruciate ligaments.

Diagnosis. *A hæmarthrosis* always follows the injury, which may be accompanied *by other minor fractures. The abnormal mobility of the* upper end of the tibia is best tested for by grasping the upper end of the tibia with the knee flexed and attempting backward and forward movements.

Treatment. This consists of complete immobilisation of the knee after aspiration of the joint by a knee fixation plaster running from the groin to just above the ankle, with the knee slightly flexed. If the anterior ligament is torn some surgeons increase the flexion, but this produces no better result and is less comfortable for the patient. Throughout treatment walking and quadriceps drill and exercises are encouraged. The plaster must be worn ten to twelve weeks, and after this a long Unna's paste stocking, extending above the knee, is worn for a further fortnight. The knee joint is usually stable after such treatment, even if there is some excessive movement in the antero-posterior plane. The results of operative reconstruction of the ligaments are no better as the tissue used stretches later on.

be carried out *in all cases in which there is radiological evidence of* opening of the joint. It is to be noted that this is often much greater if the knee is slightly flexed, and the joint should be examined in this position under anaesthesia. The post-operative treatment consists of a *stay in a walking plaster from groin to toes for six to eight* weeks (Fig. 753), during which time active exercises are carried out. In cases not submitted to operation the stay in plaster should be three months.

The incomplete lesions (*i.e.*, sprains) require a light pressure bandage in the acute stage, followed by massage, some quadriceps drill and faradism, and the building up of the shoe on the affected side to avoid further strain.



Fig. 753. Rupture of the medial collateral ligament of the knee joint. The patient placing full tension on the medial collateral ligament by supporting his body-weight on the flexed and adducted knee six weeks after operation.

Dislocations of the Patella

Dislocation of the patella is always lateral owing to the angle of pull of the quadriceps, and may be complete or incomplete. In the incomplete variety it rides up on the outer border of the lateral femoral condyle. In the complete variety it passes further and lies on the outer aspect of the condyle. In either case it is reduced by complete extension of the leg, and all that may remain after spontaneous reduction is a a synovial effusion into the knee. The important feature of the lesion is the tearing of the vastus medialis and the medial patella *retinaculum. In complete dislocation this* may be evidenced by a palpable tear in the muscle. In incomplete lesions there is little tearing, and so no question of the advisability of suture.

Treatment. This consists of aspiration of the joint, followed by a *pressure bandage, and after a few days* when bruising has subsided a firm elastic knee cap may be provided. In complete cases the treatment to commence with is the same, but an added period of immobility is necessary to allow the torn muscle to

abduction strain. Frequently the styloid process of the fibula is avulsed with the torn ligament, and a fracture of this type seen in the X-ray should raise suspicion of the lesion. On repeating the X-ray with the leg in adduction a wide opening will be seen in the outer half of the joint, in which the shadow of the avulsed fibula fragment will appear to lie. In the lateral film, however, it will be seen to lie posteriorly.

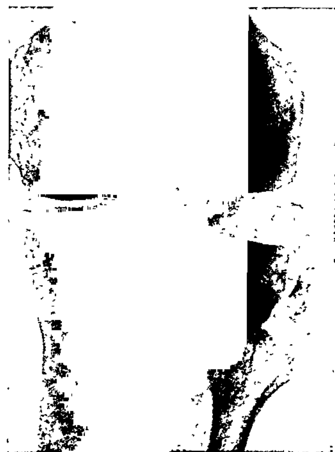


FIG. proved and might be overlooked. This figure shows the widening of the joint space on the damaged side produced by adduction (compare Fig. 571).

An interesting and common complication of this lesion is foot drop due to paralysis from stretching of the peroneal nerve. The *lesion may be incomplete and recover* rapidly, but if of any *severity is apt to* persist. The rupture of nerve fibres is intraneural and not susceptible to repair by suture. Adequate electrical stimulation of the muscles, and a plantigrade foot must be maintained during treatment of such a case, for which the prognosis is bad.

Treatment. In the first instance this consists of aspiration of the knee joint and the application of a pressure bandage. The limb is rested in extension on a Thomas splint.

Operative inspection of ruptures of the collateral ligaments will convince all that the correct treatment in all cases is open operation and repair with stainless steel wire. The ends of the ligaments are frequently widely displaced, or come to lie between a condyle and the cartilage, or else are separated by a hæmatoma. If a tight ligament is to be obtained, accurate repair is essential, and should

of X-raying the ankle in inversion or eversion is taken the rupture may be overlooked as in similar lesions of the lateral ligaments of the knee. The indications for such an X-ray are not present in every case, but when the soft tissue damage appears excessive, or small ligament traction fractures suggest tearing of the ligaments, it should be done.

Sub-astragaloid (sub-taloid) dislocation. This is a secondary dislocation involving the talo-calcaneal and talo-navicular joint. It occurs in severe torsion injuries of the foot accompanied by lateral violence to the leg. Displacement may be either medial or lateral, anterior or posterior, the most common lesion being medial. The treatment is immediate reduction by manipulation and plaster (see p. 611).



FIG. 756 Dislocation of the second metatarsal accompanied by a fracture of the base of the third metatarsal and of the neck of the third and fourth metatarsals There is a subluxation of the first metatarso-cuneiform joint.

Sprain of the mid-tarsal joint. This lesion is commonly mistaken for sprain of the ankle. The swelling and pain are localised in front of the ankle, but the distinction depends on the fact that ankle movements are free and painless, but when the calcaneus is steadied pain is produced on inversion or eversion of the foot. A small ligament strain fracture of the cuboid may accompany the lesion.

Dislocation at the mid-tarsal joint. This rare lesion is indicated by prominence of the talus on the dorsum of the foot with plantar displacement of the forefoot. It may resemble a posterior sub-astragaloid dislocation. The injury producing such a dislocation is severe, and so commonly compound, the joints frequently being exposed. Treatment follows the lines for sub-taloid dislocations, or those for compound fractures.

Dislocations at the tarso-metatarsal joints. The first and the fifth metatarsals are the most commonly involved, but the lesion is uncommon The dislocation is usually dorsal and the prominence of the base of the metatarsal is easily recognised. Traction on the

regenerate, so that the knee is put into a knee fixation plaster for three to four weeks. After this an elastic knee cap is worn.

If after a traumatic dislocation has occurred it shows a tendency to recur, then some operative repair of the vastus medialis and the patella retinaculum may be contemplated. Excision of the patella or transplantation of the tibial tubercle are also used.

Dislocation of the Upper End of the Fibula

The upper end of the fibula is sometimes dislocated by direct *violence which is very liable to damage the peroneal nerve at the*



Fig. 754. Dislocation of the head of the fibula. Antero-posterior view. The head of the fibula is much more completely visible than normal



Fig 755. Lateral view of the same case showing the fibula lying more anterior than usual.

same time The dislocation is antero-lateral, and the blow to cause this comes partly from behind and partly from the side. The symptoms resemble those of fracture of the upper end of the fibula from which it is, as a rule, only distinguished by X-ray Reduction is simply brought about by direct pressure over the head of the bone where it appears most prominent, with the knee flexed A firm support to the knee for a week or longer is provided by an Unna's paste bandage. The condition clears up leaving no disability.

Dislocations of the Ankle

The lesions which may affect the talus and its articulations have already been briefly listed in Chapter XXXIII. Once again we would like to *emphasise that primary dislocations at the ankle joint* may occur without fracture of a malleolus, and unless the precaution

GALLIE and LEMESURIER. "The Repair of Injuries to the Posterior Cruciate Ligaments of the Knee," *Ann. Surg.*, 1927, **85**, 592.
RITTER. "Dislocation of the Knee Joint," *J. Bone and Joint Surg.*, 1932, **14**, 391.

Fibula

BUTLER, W. J. "Isolated Traumatic Dislocations of the Fibula Head," Univ. Hosp. Bull. (Ann Arbor), 1946, **12**, 73-75.

Foot

BONNIN, J. G. "Dislocations and Fracture Dislocations of the Talus," *Brit. J. Surg.*, 1940 41, **27**, 88.
SHANDS, A. R. "The Incidence of Subastragaloid Dislocation of the Foot, with the Report of One Case of the Inward Type," *J. Bone and Joint Surg.*, 1928, **10**, 306.
BONNIN, J. G. "Injuries to the Ankle." Wm. Heinemann (Medical Books) Ltd. London, 1950.

toe with pressure on the metatarsal base reduces the displacement, after which it is immobilised in plaster for two to four weeks.

Dislocation of a metatarsal. In compound injuries this may occur. It is of rare occurrence in the intact foot (Fig. 756). Reduction by manipulation should be attempted, but the proximal end of the bone may be difficult to reduce and open reduction required. Immobilisation in plaster is necessary, but should not be persisted in longer than is necessary for the bone to form a stable bed for itself. Active non-weight bearing exercises, massage and faradic foot baths should be given till a painless foot results and then weight bearing is commenced.

Dislocations of the metatarso-phalangeal and inter-phalangeal joints. These resemble the similar lesions of the hand. The dislocation is usually dorsal, and is easily reduced, showing little tendency to recur. Strapping around the metatarsus with a pad over the dislocated phalanx is usually sufficient fixation. In the more serious cases involving the big toe, especially if compound, a walking plaster with fixation of the great toe may be necessary.

FURTHER READING

Sacro-iliac Joint

BROOMHEAD. "Dislocation of the Sacro-iliac Joint Reduced by Hokes Traction," *Proc. Roy. Soc. Med.*, 1933, 27 (1), 576.

Hip

FUNSTEN, KNISER and FRANKEL. "Dashboard Dislocations of the Hip," *J. Bone and Joint Surg.*, 1938, 20, 124.

CAMPBELL, W. C. "Posterior Dislocation of the Hip with Fracture of the Acetabulum," *J. Bone and Joint Surg.*, 1936, 18, 842.

PLATT, H. "On Some Complications of Traumatic Dislocation of the Hip," *Brit. J. Surg.*, 1932, 19, 601.

URIST, M. R. "Fracture Dislocation of the Hip," *J. Bone and Joint Surg.*, 1948, 30A, 699–727.

ARMSTRONG, J. R. "Traumatic Dislocation of the Hip Joint," *J. Bone and Joint Surg.*, 1948, 30B, 430.

THOMPSON, V. P., and EPSTEIN, H. C. "Traumatic Dislocation of the Hip," *J. Bone and Joint Surg*, 1951, 33A, 746.

Knee

CALLEN. "Pellegrini-Steida's Disease," *Radiology*, 1937, 29, 158. (With full references.)

CONWELL and ALDREDGE. "Complete Dislocation of the Knee Joint," *Surg. Gynæ. and Obstets.*, 1937, 64, 94. (With bibliography.)

KLEINBURG. "Traumatic Lateral Dislocation of the Patella," *Ann. Surg.*, 1932, 95, 635.

HEY GROVES. "The Cruciate Ligaments of the Knee Joint," *Brit. J. Surg.*, 1919–20, 7, 505.

JONES and SMITH. "On Ruptures of the Cruciate Ligaments of the Knee, and on Fractures of the Spine of the Tibia," *Brit. J. Surg.*, 1913, 1, 70.

5. Retention. Plaster.
   Continuous traction.
   Special splints.
6. Re-education. Massage.
   Active and passive movements.
   Electrical stimulation of muscles.
   Exercises and weight bearing.
7. Length of immobilisation, likely disability, and later sequelæ.
8. Complications. In outline only.

2. Discuss the diagnosis of, *e.g.*, fracture of the neck of the femur.
This includes :

The general signs and symptoms of fractures.
The special signs and symptoms of this particular fracture.
A brief outline of the differential diagnosis.

3. Discuss the complications of fracture of the shaft of the humerus.
This includes :

The immediate complications.
The intermediate complications.
The late complications and sequelæ.

And a brief outline of their treatment.

4. Discuss the treatment of fractures of the tibia.
This includes :

First aid measures.
The three " R's," reduction, retention and re-education.

5. What are the indications for operation in the case of fracture of a long bone ?
These may be divided according to time into :

Immediate. (Compound, failure of manipulation.)
Intermediate. (Fractures of certain bones, *e.g.*, the patella. Infection.)
Delayed. (Non-union, mal-union, false joint formation, osteomyelitis.)

6. Questions on side-lines :
Discuss non-union.
Describe the repair of fractures.
What do you understand by " avascular necrosis ? "

7. Questions may be combined as in the following M.B., B.S. questions :
What is a Colles's fracture ? Describe the signs, symptoms and treatment.
Discuss the pathology, diagnosis and treatment of a fracture of the lower jaw. Describe briefly the complications which may arise.
Describe the investigation and treatment of fracture of the spine without paralysis.

APPENDIX I

FRACTURE QUESTIONS AND PAPERS

THE art of answering an examination paper has been brought up to a high pitch, and to do justice to oneself and the paper one must adopt a settled approach to it. This approach is based on the facts that in the first few minutes after perusing the questions matter comes to mind, which may be found difficult to remember later, that while answering one question, the "subconscious" is busy assembling facts for the next, and that equal answers to all questions obtain the highest marks, and so equal distribution of time over the answers is important. Most examinees adopt the following scheme, or some slight modification of it.

In a three hour exam, the first fifteen minutes is devoted to the consideration of the paper, firstly, the questions selected for answering, secondly, their relative difficulty to oneself, and, thirdly, to scheme out an answer to the easiest, and at the same time jot down any ideas occurring to the mind about the other questions. A further quarter hour is deducted from the time for use at the end of the exam to re-read questions, correct, if necessary, and add the finishing touches to a question which has taken longer than allowed. The remainder of the time (two and a half hours) is divided equally among the questions. The easiest question is answered first, and this may result in saving some time for a difficult question at the end of the paper. The set-out of the question is important, and it is a good plan to include the summary on which one has built up the answer at the head of the answer. Accurate division into paragraphs corresponding to the summary is then possible.

Fracture questions are limited in form, if not in variety, and they will be found to fall among the following types.

1. Discuss a fracture, *e.g.*, fractures of both bones of the forearm.

This is a very long question, and a complete summary of an answer to such a question is given, as more frequently some component part, such as the diagnosis, or treatment, is asked for.

It includes :

1. Introduction. Brief description of type and structure of the bone. Enumeration of the fractures affecting it, and outline of the common mechanisms and occupational hazards, if any, responsible.
2. Symptoms and signs. (*a*) General. (See Chapter III,)
   (*b*) Special, for the particular fracture.
3. Displacement. (*a*) The exciting causes.
   (*b*) The influence of gravity.
   (*c*) Muscles.
   (*d*) First-aid prevention of further displacement.
4. Reduction. {Immediate. / Delayed.} Method. {Manipulation. / Continuous traction. / Operation.}
   Suitable type of anæsthesia.

5. Retention. Plaster.
   Continuous traction.
   Special splints.
6. Re-education. Massage.
   Active and passive movements.
   Electrical stimulation of muscles.
   Exercises and weight bearing.
7. Length of immobilisation, likely disability, and later sequelæ.
8. Complications. In outline only.

2. Discuss the diagnosis of, *e.g.*, fracture of the neck of the femur.
This includes :

The general signs and symptoms of fractures.
The special signs and symptoms of this particular fracture.
A brief outline of the differential diagnosis.

3. Discuss the complications of fracture of the shaft of the humerus.
This includes :

The immediate complications.
The intermediate complications.
The late complications and sequelæ.

And a brief outline of their treatment.

4. Discuss the treatment of fractures of the tibia.
This includes :

First aid measures.
The three "R's," reduction, retention and re-education.

5. What are the indications for operation in the case of fracture of a long bone ?
These may be divided according to time into :

Immediate. (Compound, failure of manipulation.)
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What do you understand by "avascular necrosis ?"

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Discuss the pathology, diagnosis and treatment of a fracture of the lower jaw. Describe briefly the complications which may arise.
Describe the investigation and treatment of fracture of the spine without paralysis.

APPENDIX II

FRACTURE INDEX AND DISABILITY TABLES

The endeavour to fix a definite disability period for each fracture is fruitless, and quite impossible owing to individual variation in the lesions. It is, however, sometimes useful to have a rough guide against which one can compare one's own results, and which may draw attention to certain inequalities in healing time in apparently similar bones. More important than the disability period is the ordered terminology of the lesions which enables a fracture cross-index to be kept, and which should be standardised to facilitate comparison of various clinics.

USE OF TABLES

In the first column are given the periods of usual recumbency, following this is the period of non-weight bearing and weight-bearing fixation. In the next column is the period of exercise in the "Massage" department necessary to restore function sufficiently for light work. In the fourth column the approximate period of light work necessary before the patient is fit for heavy work is given. In many cases the period of "exercises" can be included in this, thus shortening the total disability. In the last column is given the total period, including all the previous periods, before the patient is restored to full work. Taking an oblique fracture of the tibia treated by skeletal traction as an example, we see that it requires two to four weeks in bed with skeletal traction, which is followed by a plaster for four to six weeks (extending to the ischium) in which the patient is encouraged to walk. On removal of this an Unna's paste or similar stocking is necessary for three weeks, while it takes the patient eight to twelve weeks to get used to walking on his injured leg, during which period he may be regarded as fit for light work. At the best he will be unable to work for sixteen weeks (a young patient) and at the worst his average *disability period is thirty weeks. Compare this with a transverse fracture* plated and an oblique fracture treated with a single screw.

Fracture (Arranged in order suitable for indexing)	Recumbent Period	Non-Weight bearing Plaster = P	Ambulant Plaster (Weight bearing)	Re-education		Total Disability.
				Period of Exercises	Light Work	
	All periods expressed in weeks are approximate and may overlap 1/7 = 1 day					
SKULL						
Fractures with complications						
,, without complications						
FACE AND JAW						
Zygoma . . .	*Depends on associated injuries.*	—	—	—	—	1–8
Maxilla . . .		—	—	—	—	1–12
Nasal bones		—	—	—	—	2/7–2
Mandible, Simple		—	—	—	—	6–12
Compound.		—	—	—	—	12–78

Fracture (Arranged in order suitable for indexing)	Recumbent Period.	Non-Weight bearing Plaster = P.	Ambulant Plaster (Weight bearing)	Re-education.		Total Disability.
				Period of Exercises.	Light Work.	
	All periods expressed in weeks are approximate and may overlap. 1/7 = 1 day.					
SPINE						
Cervical V. / Dorsal V. / Lumbar V. — *a.* Without cord damage.	3	—	20	—	20	24–36
b. With cord damage.	?	—	16–26	—	26	24–66
Sacrum and coccyx . .	1	—	—	—	2–7	3–10
Accessory processes . .	1/7–1	—	—	2	3	5
RIBS AND STERNUM						
Without visceral injury .	1/7–1		Strap 3	1	4	5–12
With visceral injury . .	1–6	—	—	3	—	3–16
Sternum	1/7–1	—	—	—	3–6	4–12
CLAVICLE						
Age 1–10	—	—	Sling 2	—	—	3
10–20 . . .	—	—	„ 2–3	2	1–2	4–5
20–40 . .	0–2	—	„ 3	2–3	2–6	6–12
40 . . .	2/7–2	—	„ 3–4	3–4	4–8	8–18
SCAPULA						
Process	0–1	—	Sling 2	2	2	2–8
Body	0–2	—	„ 2	3–4	4–6	4–12
HUMERUS						
Upper end. Impacted	0–1	—	Sling 3–5	4–5	4–12	8–16
Unimpacted .	1–3	—	„ 2–4	4–5	4–12	8–36
Tuberosity . .	0–1	—	3–4	1–2	4–12	5–12
Shaft	2/7–3	—	3–10	2	4–8	8–18
Lower end. Complete.						
Flexion and T-shaped .	1–3	—	3	Sling 2	4–12	8–26
Extension .	1–3	—	3	„ 2	3–8	7–12
Supracondylar and epiphyseal . .	—	—	3 or	Sling 3	—	3–5
Incomplete . . .	—	—	3 or	„ 3	—	3–8
RADIUS						
Head	0–1	—	2–4	Sling 1	3–6	4–10
Shaft Greenstick . .	Nil.	—	2–3	Nil.	—	3–4
Adult . .	0–1	—	3–6	—	2–4	5–8
Colles's (or Smith's) :						
No displacement . .	—	—	2–3	1	2–4	4–6
Displacement . .	—	—	3–4	2	4–6	7–9
Comminuted behind joint	—	—	4–5	3	6–8	10–11
Comminuted into joint	—	—	5–6	4–10	8–10	12–18
Marginal fractures . .	—	—	2–4	—	2–4	4–8
ULNA						
Olecranon	4/7–10/7	—	2–3	Sling 2	4–8	6–12
Shaft alone . . .	0–1	—	3–6	3	3–5	5–10
with head of radius	3/7–1	—	4–7	4	8–16	12–26
Both bones of the forearm.	0–3	—	6–18	2–6	6–26	12–52
Styloid process and lower end	Nil.	—	Sling 2	—	3–4	3–4
CARPUS						
Navicular and other single bones . . .	—	—	6–16	—	4–10	10–26
Fractures with dislocation .	—	—	6–16	—	4–10	10–26

APPENDIX II

FRACTURE INDEX AND DISABILITY TABLES

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Fracture. (Arranged in order suitable for indexing.)	Recumbent Period.	Non-Weight bearing Plaster = P.	Ambulant Plaster (Weight bearing.)	Re-education		Total Disability.
				Period of Exercises	Light Work	
	All periods expressed in weeks are approximate and may overlap 1/7 = 1 day.					
SKULL						
Fractures with complications						
" without complications						
FACE AND JAW						
Zygoma	Depends on associated injuries.	—	—	—	—	1–8
Maxilla		—	—	—	—	1–12
Nasal bones		—	—	—	—	2/7–2
Mandible, Simple		—	—	—	—	6–12
Compound		—	—	—	—	12–78

Fracture. (Arranged in order suitable for indexing.)	Recumbent Period.	Non-Weight bearing Plaster = P	Ambulant Plaster (Weight bearing.)	Re-education.		Total Disability.
				Period of Exercises.	Light Work.	
	All periods expressed in weeks are approximate and may overlap 1/7 = 1 day					
ANKLE						
External Rotation fractures						
1st degree. Mild . .	0-1/7	—	Unna's 1-2	—	2-3	3-5
Severe .	1/7-1	1-2	W.P. 2-4	—	2-4	4-8
2nd degree . . .	1-2	2-3	" 4-6	Unna's 2	8-12	10-15
3rd degree . . .	1-4	3-4	" 5-9	" 2	8-16	12-24
Abduction fractures						
1st degree . . .	1-2	—	W.P. 2-4	—	2-4	5-10
2nd degree . . .	1-2	2-3	" 4-6	2-4	8-12	12-18
3rd degree . . .	2-3	2-3	" 4-8	6-10	8-20	12-24
Adduction fractures . .						
1st, 2nd, 3rd degree .	*Same as for abduction fractures.*					
Compression fractures .	—	—	—	—	—	—
Fractures with diastasis .	—	—	—	—	—	—
TARSUS						
Calcaneus						
"Beak," tuberosity, sustentaculum tali.						
Crush fractures of body	2-6	4-12	4-8	Unna's 3	12-26	26-70
Other bones, including sesamoids	—	1-3	—	—	—	—
METATARSUS	0-2	1-4		1-4	4-8	4-8
PHALANGES. TOES						
Great toes . . .	—	—	—	—	—	1-5
Other toes . . .	—	—	—	—	—	1-3

Fracture. (Arranged in order suitable for indexing)	Recumbent Period.	Non-Weight bearing Plaster = P.	Ambulant Plaster (Weight bearing)	Re-education.		Total Disability.
				Period of Exercises.	Light Work.	
	All periods expressed in weeks are approximate and may overlap. 1/7 = 1 day.					
METACARPALS						
Bennett's fracture. (1st) .	—	—	3	—	4	6–10
Other metacarpals . .	—	—	3	—	4	4–6
PHALANGES. FINGERS						
Not involving joints . .	—	—	3	2	3	3–4
Involving joints . .	—	—	4	2–6	6–10	4–16
PELVIS						
Ring fractures. Single .	4–8	—	—	—	4–8	10–14
Double .	8–12	—	—	—	8–12	16–26
Processes.	3/7–2	—	—	—	—	2–6
FEMUR						
Upper end. Medial						
Abduction	1–2	—	10–14	10	12–16	12–26
Adduction . . .	1–6	—	—	—	8–12	12–52
Per-trochanteric . .	8–10	—	—	Calliper 12–16	16–20	32
Epiphyseal separations .		—	Calliper 26	26	12–16	30–52
Greater and lesser trochanter	4–6	—	—	—	3–6	4–8
Shaft. Upper Third (Subtrochanteric)	4/7–1 4–8	4–8	4–6	4–6	4–10	18–32
Middle Third. Oblique (Traction)	4–8	4–8	4–8	4–8	4–12	12–40
Transverse Plate	2	—	4–8	Throughout.	4–12	16–25
Plaster	2–4	4–6	4–6	4–10	4–12	16–32
Comminuted	4–6	4	4–6	4–10	6–12	20–48
Condylar.	4–8	4–6	W.P. 4–8	16	8–26	16–52
				or		
PATELLA						
Without separation .	1/7–1	—	4–6	Unna's 2	2–6	8–14
With separation .	*1–2*	—	*4–6*	,, 2	*5–12*	*12–26*
				or		
TIBIA						
Upper third						
Spine	1–2	—	4–6	Unna's 2	3–6	7–12
Tuberosities . .	1–6	3–6	4–6	,, 3	6–52	10–76
Shaft. *Greenstick* . .	*0–1*	—	*3–5*	—	*1*	*4–6*
Adult. Oblique	2–4	—	4–6	Unna's 3	12–18	16–36
Transverse	1–3	1–3	5–7	,, 3	12–30	16–42
Both bones of the leg						
Oblique. Traction .	3–5	4	4–6	4–8	8–12	16–30
Transverse. Plaster	1–3	2–4	4–12	4–8	8–12	16–48
Oblique Screw .	2	4	6	2–4	4–8	15–30
Transverse Plate	2	0–2	8–10	Throughout.	4–6	17–32
Lower Third .	1–3	0–2	4–6	4–8	8–10	16–28
FIBULA						
Head	—	—	Unna's 1–3	—	2–3	3–5
Shaft	—	—	,, 1–3	—	2–3	3–6
Lower end . . .	—	—	,, 1–3	—	2–3	3–5

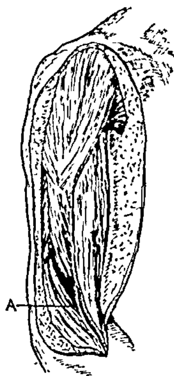


Fig. 759. Exposure of the superficial muscles by Henry's incision. A. The cephalic vein and musculocutaneous nerve.

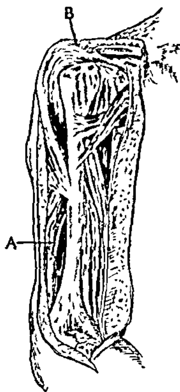


Fig. 760. Complete exposure of the humerus by Henry's approach. It is necessary to flex the elbow to visualise the lower third: A. Radial nerve. B. Small flake of clavicle reflected with origin of the deltoid.

third retraction of the deltoid is unsatisfactory, and if the shoulder has to be approached a slip of the attachment of the deltoid to the clavicle is divided with a chisel, and the deltoid turned back. This of course needs an extension of the primary incision towards the acromion (Fig. 760 B). If a partial exposure of the bone is needed a long superficial incision is necessary to allow adequate retraction.

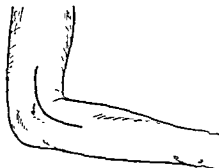


Fig. 761. Incision for exposure of the elbow joint (Author's method).

2. The Elbow Joint. *Modified Lateral Approach.* An incision commencing 2 inches above the lateral epicondyle is continued along the anterior border of the brachio-radialis, *i.e.*, a curved incision centred on the epicondyle, with the elbow flexed to a right angle. The lateral intermuscular septum is exposed above with the triceps behind it. Arising from its lateral edge and continuing down to the epicondyle are the brachio-radialis, the extensor carpi-radialis longus and brevis. Behind these, over the head of the radius, are a few fibres of supinator and the orbicular ligament. A firm incision is made from the epicondyle down to the neck of the radius,

APPENDIX III

SURGICAL EXPOSURE OF THE LONG BONES

1. Humerus and Shoulder Joint. The humerus is more difficult to approach than the femur, though not surrounded by such a depth of muscle. This is due to the double layers of muscle overlapping the upper and lower ends of the bone, and the close relationship of the neuro-vascular bundle *medially*, the *radial nerve dorsally*, and the *musculo-cutaneous nerve anteriorly*.

A. K. Henry's Approach. This may be used to approach the whole length of the bone. The incision (Fig. 757) follows the course of the cephalic vein

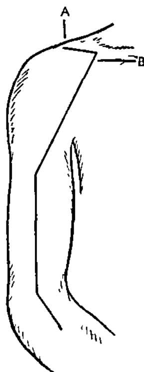


Fig. 757. Henry's incision for complete exposure of the humerus.

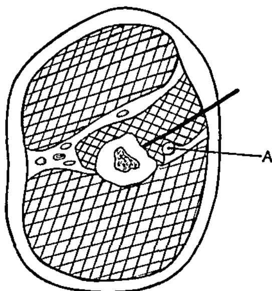


Fig 758. The line of incision through the brachialis. A = The radial nerve.

between the contiguous borders of the deltoid and pectoralis major, and then passes down the lateral side of the biceps. The incision is deepened through the fascia, and the humerus exposed at the lower border of the deltoid. The brachialis anticus, running down from this, is then divided so that a quarter of the muscle is left to the outer side protecting the radial nerve. If further exposure is desired the radial nerve is identified at the upper postero-lateral angle of the brachialis and retracted while the humerus is cleared with a rugine. The bone can be exposed below to two fingers' breadths above the lateral epicondyle without entering the elbow joint, but in order to allow satisfactory retraction of the muscles the elbow must be flexed. In the upper

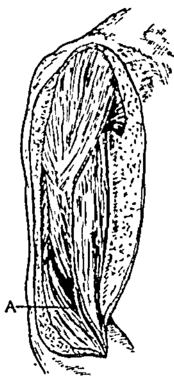


Fig. 759. Exposure of the superficial muscles by Henry's incision. A. The cephalic vein and musculocutaneous nerve.

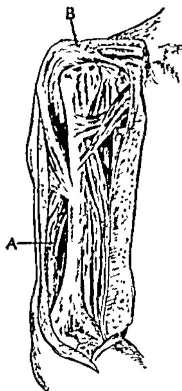


Fig. 760. Complete exposure of the humerus by Henry's approach. It is necessary to flex the elbow to visualise the lower third: A. Radial nerve. B. Small flake of clavicle reflected with origin of the deltoid.

third retraction of the deltoid is unsatisfactory, and if the shoulder has to be approached a slip of the attachment of the deltoid to the clavicle is divided with a chisel, and the deltoid turned back. This of course needs an extension of the primary incision towards the acromion (Fig. 760 B). If a partial exposure of the bone is needed a long superficial incision is necessary to allow adequate retraction.

2. The Elbow Joint. *Modified Lateral Approach.* An incision commencing 2 inches above the lateral epicondyle is continued along the anterior border of the brachio-radialis, *i.e.*, a curved incision centred on the epicondyle, with the elbow flexed to a right angle. The lateral intermuscular septum is exposed above with the triceps behind it. Arising from its lateral edge and continuing down to the epicondyle are the brachio-radialis, the extensor carpi-radialis longus and brevis.

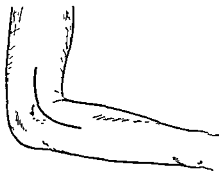


Fig. 761. Incision for exposure of the elbow joint (Author's method).

Behind these, over the head of the radius, are a few fibres of supinator and the orbicular ligament. A firm incision is made from the epicondyle down to the neck of the radius,

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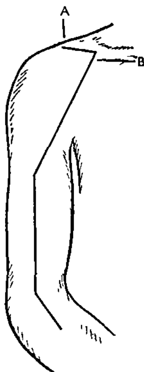


Fig. 757. Henry's incision for complete exposure of the humerus

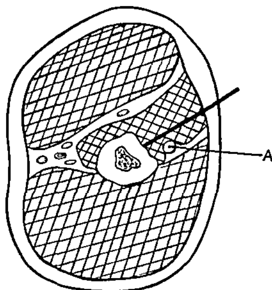


Fig. 758. The line of incision through the brachialis. A = The radial nerve.

between the contiguous borders of the deltoid and pectoralis major, and then passes down the lateral side of the biceps. The incision is deepened through the fascia, and the humerus exposed at the lower border of the deltoid. The brachialis anticus, running down from this, is then divided so that a quarter of the muscle is left to the outer side protecting the radial nerve. If further exposure is desired the radial nerve is identified at the upper postero-lateral angle of the brachialis and retracted while the humerus is cleared with a rugine. The bone can be exposed below to two fingers' breadths above the lateral epicondyle without entering the elbow joint, but in order to allow satisfactory retraction of the muscles the elbow must be flexed. In the upper

insertion of the biceps, the supinator edge lying just beside this. The pronator quadratus is detached below and retracted in.

ULNA. This is exposed along the dorsal subcutaneous border.

WRIST. *Dorsal Approach.* The incision runs along the dorsal axis of the limb just radial to the extensor indicus proprius. The dorsal carpal ligament is divided, and the extensor pollicus longus retracted laterally, and the radial extensors with it. The joint is then opened.

Anterior Approach. This is undesirable owing to the risk of tendon damage and damage to nerves. The incision runs along the border of palmaris longus and is deepened, exposing the median nerve. Retraction of the tensons

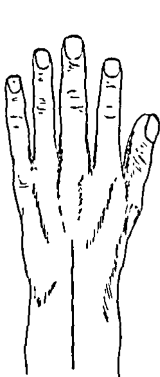


FIG 764. Posterior approach to the wrist joint.

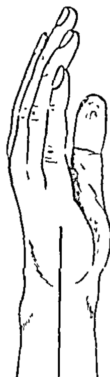


FIG. 765. Lateral (ulna) approach to the wrist joint.

then allows inspection of the carpal tunnel and the removal of the volar dislocated lunate.

Medial Approach. A vertical incision is made on the ulnar border of the hand centred on the ulna styloid process, and extending from the middle of the fifth metacarpal to 2 inches above the lower end of the ulna. The dorsal branch of the ulnar nerve is met with at the proximal end of the incision. Extensor carpi ulnaris is then divided at its insertion into the base of the fifth metacarpal, and the dorsal aspect of the carpus cleared by raising the extensor tendons. If an anterior approach is desired the pisiform and the hook of the hamate must be divided from the carpal bones.

FEMUR. *Henry's Approach.* The incision runs from the anterior superior iliac spine to the lateral side of the patella. The space between the rectus femoris and the vastus lateralis is defined, and the two muscles separated. The conjoined tendon below is divided by the knife. The vastus intermedius is thus exposed, being crossed above the neuro-vascular bundle to the vastus

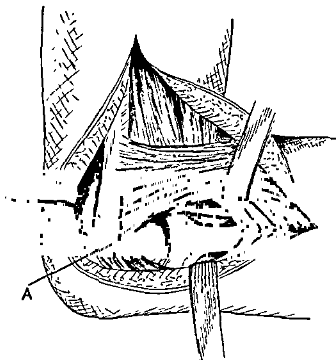


Fig. 762. Exposure of the elbow joint (Author's method). Retraction of the triceps shows the olecranon fossa. Upward retraction of the radial extensor group and division of the supinator exposes the head *of the radius. Further division of the flexor group (A) exposes more* of the anterior compartment of the joint as desired.

stopping threequarters of an inch below the head to avoid risk of damage to the deep branch of the radial nerve in the supinator muscle. The lower half of this incision is that employed for exposure of the head of *the radius. By extending the elbow and separating* the triceps from the back of the humerus retraction enables the olecranon fossa to be viewed obliquely. Division of the common extensor origin to the epicondyle enables the anterior aspect of the joint to be approached. If the head of the radius has to be removed, its removal gives sufficient exposure without this procedure.



Fig. 763. Langenbeck's incision for exposure of the elbow centred posteriorly on the olecranon.

Posterior Approach. Langenbeck's Method. A vertical incision is placed in the mid-line over the posterior aspect of the joint centred on the olecranon tip. The triceps is divided in the line of the incision above and the anconæus below The joint is exposed by separating the muscles from the bone.

Radius. Head (see above). The whole of the shaft may be exposed by an incision along the anterior border of the brachio-radialis, which marks the line of division of the nerve supply between the radial nerve to the outer side and the median nerve to the inner side. The radial artery and the superficial division of the radial nerve lie in the line of the incision below. The artery is retracted *medially and the nerve laterally.* The supinator may be cleared from the bone above by finding the edge of its attachment. This is best done by following down the

insertion of the biceps, the supinator edge lying just beside this. The pronator quadratus is detached below and retracted in.

ULNA. This is exposed along the dorsal subcutaneous border.

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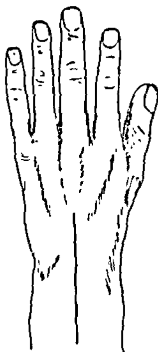


FIG. 764. Posterior approach to the wrist joint.



FIG. 765. Lateral (ulna) approach to the wrist joint.

then allows inspection of the carpal tunnel and the removal of the volar dislocated lunate.

Medial Approach. A vertical incision is made on the ulnar border of the hand centred on the ulna styloid process, and extending from the middle of the fifth metacarpal to 2 inches above the lower end of the ulna. The dorsal branch of the ulnar nerve is met with at the proximal end of the incision. Extensor carpi ulnaris is then divided at its insertion into the base of the fifth metacarpal, and the dorsal aspect of the carpus cleared by raising the extensor tendons. If an anterior approach is desired the pisiform and the hook of the hamate must be divided from the carpal bones.

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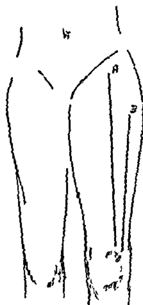


FIG. 766. The approach to the femur. A. Henry's approach. B. Lateral approach.



FIG. 767. The muscles of the thigh showing relation to Henry's incision.



FIG. 768. The vastus intermedius exposed after dissection of the gap between the rectus femoris and the vastus lateralis—line of incision indicated. Note the crossing of the vastus intermedius by the lateral circumflex vessels and the nerve to the vastus lateralis.

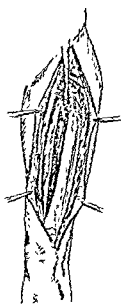


FIG. 769. The shaft of the femur exposed, with the lateral circumflex vessels and the nerve to the vastus lateralis retracted upwards.

medialis. This bundle is readily mobilised and retracted *proximally*. The vastus intermedius is then divided down to the bone, in the line of its fibres, and the *muscle stripped from* the femur. In order not to expose the supra-patellar pouch, which extends 3 inches above the patella, the incision through the crureus must not go below this level. The pouch can be separated from the bone by a rugine if desired, and a wider exposure obtained.

Lateral Approach. The incision runs from the greater trochanter to the lateral condyle of the femur. *The ilio-tibial band is split throughout its* length and the vastus externus divided down to the bone. Numerous vessels are encountered in this step, the perforating branches and the lateral circumflex artery. Muscle damage and hæmorrhage make it an unpleasant approach

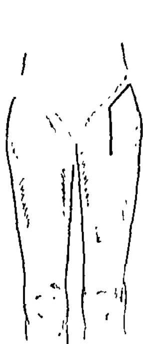


Fig. 770. Smith-Peterson approach to the hip. Skin incision.



Fig. 771. The incision for the posterior approach to the hip.

to employ, and vision is restricted unless the patient is lying on the opposite side.

Posterior Approach. This is a useful approach to the middle three-fifths of the shaft as it avoids further damage to the quadriceps. Its only disadvantage is the need to tie off the perforating vessels. A mid-line posterior incision is made. The *hamstrings are easily separated* with the fingers, and the linear aspera felt. The long head of the biceps will be found to cross the wound obliquely. If access to the upper half of the shaft is desired, it is retracted medially with the sciatic nerve, which it protects. If access is required to the lower half of the femur, its tendon is divided in the lower half of the wound, and the long head retracted medially, *again with the sciatic nerve*. There is danger of damage to the nerve if the whole middle three-fifths of the bone is exposed by retracting it laterally.

HIP. *Smith-Peterson or Lateral Approach*. The incision runs down from the anterior superior iliac spine and backwards along the crest of the ilium for 3 inches. The sartorious and rectus *femoris are separated* together on the

medial side, and the tensor fasciæ femoris and glutæus minimus on the outer side.

The tensor fasciæ lata and anterior parts of the glutei are then stripped from the outer aspects of the ilium. The superior surface of the joint and the femoral neck are thus exposed.

Posterior Approach (Gibson's modified Kocher). The short angular Kocher incision shown is extended upwards in the line of the gluteal fibres towards the posterior superior iliac spine, and the lower down the shaft of the femur on

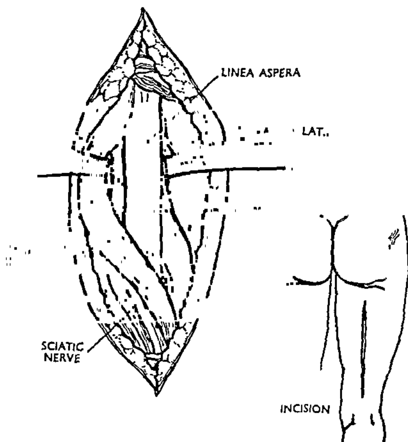


Fig. 772 The posterior approach to the femur, which is useful in fractures of the middle three-fifths of the shaft.

its anterior margin, the patient of course lying on the side. The gluteal bursa is opened, and the incision carried downward in the line of the fibres of the fascia lata for 4–5 inches. The incision is then extended obliquely upward in the anterior part of the glutæus maximus where there is chiefly fascia. Retraction of the fascia, facilitated by flexing the thigh, exposes the insertions of glutæus medius and glutæus minimus and the other short rotators, which are divided around the top of the trochanter and the capsule of the hip exposed. This is incised and dissected from the aletabular margin and the trochanter. The head of the femur can then be readily dislocated by external rotation and flexion. This gives access to the rest of the capsule and to the acetabulum. Retraction is easier and less hæmorrhage is encountered than in the Smith-Petersen approach.

Knee. There are a variety of approaches dependent on the procedure to be carried out. These are too numerous to be detailed here. The oblique

incision for the removal of a meniscus is recommended and this may be extended into the quadriceps expansion for further exposure, producing in effect the patella displacing incision of Timbrell Fisher.

Popliteal Surface. This may be exposed from the medial side by an incision in line with the tendon of the adductor magnus and free dissection behind that muscle: or, on the outer side, by an incision along the posterior border of the ilio-tibial band. The lateral intermuscular septum runs in from here and dissection along its posterior face exposes the popliteal space.



Fig. 773. Approach to the knee. The incision for medial menisectomy is indicated by the black line. Dotted lines indicate suitable extensions for more elaborate procedures—the incision for lateral menisectomy may be similarly treated.

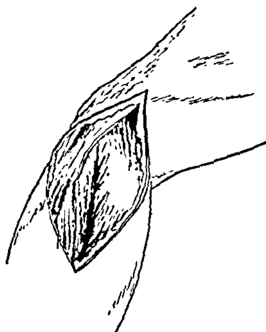


Fig. 774. The exposure of the upper third of the fibula, showing the peroneal nerve winding around the neck of the bone to disappear into peroneus longus.

Tibia. This is subcutaneous and can be exposed throughout its whole length by an anterior or antero-medial incision.

Fibula. Rarely exposed. It is only necessary to remember that the peroneal nerve winds around the neck of the bone. The bone is exposed by an incision along its whole length and separation of the soleus from the peronei.

Ankle. A direct approach by a curved incision over either malleolus is employed in dealing with fractures of the malleoli. The incision is curved anteriorly or posteriorly. Approach to the posterior aspect of the joint may be made on the lateral or medial side. The lateral side is free of vessels and nerves, but owing to the relationship of the bi-malleolar axis to the antero-

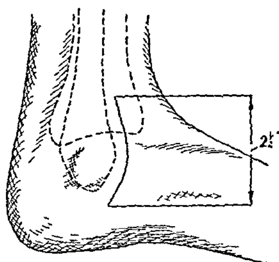


Fig. 775. *Curved incision to expose the medial or lateral malleolus.*

posterior axis of the ankle gives a more limited exposure than the medial approach. For fractures of the posterior tubercle the lateral approach is used. For posterior marginal fractures the lateral approach. In the medial approach the posterior tibial nerve and artery and the tendon of *flexor hallucis longus* has to be avoided (Fig. 685), and the direct view is obscured by the tendo Achilles. Complete exposure of the posterior aspect of the joint can only be chieved by division of the tendon.

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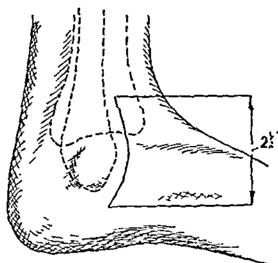


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